INTERAVIA

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with Electronics Supplement

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VOLUME XVI

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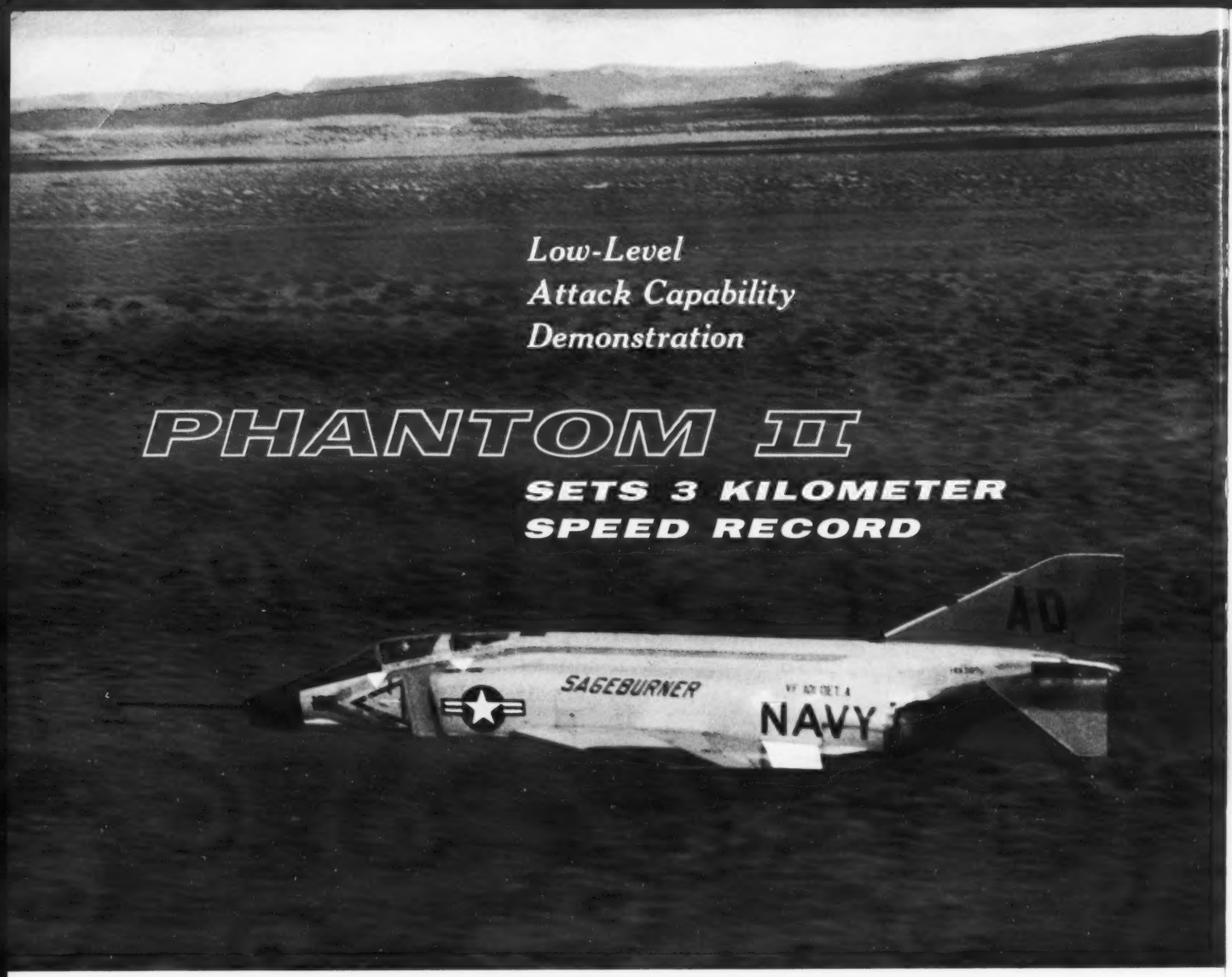
No. 11 / 1961



A Phantom II has established another World's Speed Mark.

Flying nearly 15 miles a minute, at times less than 100 feet above the ground, a McDonnell Phantom II swept through a measured 3-kilometer course in 7.5 seconds to capture a record that has stood for eight years.

Pilot Lt. Hunt Hardisty and Radar Intercept Officer Lt. Earl H. DeEsch flew the twin jet fighter the required four times through the tight low altitude course, never climbing above 500 feet, even during the turns to re-enter the measured straightaway.

The old record of 753 mph was held by an XF4D. The Phantom II slammed through the hot desert air at an average speed of 902.77 mph.

The record run, code named "Operation Sageburner," emphasized the low altitude attack capability of the U. S. Navy's newest all-weather air defense and ground attack fighter. In previous record setting flights, the Phantom II climbed to 98,557 feet, set world's 100 and 500-kilometer closed course speed marks, and flew coast to coast in 170 minutes.

Maximum speed of the Phantom II is in excess of 1500 mph.

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Volume XVI

INTERAVIA

November 1961

WORLD REVIEW OF AVIATION AND ASTRONAUTICS

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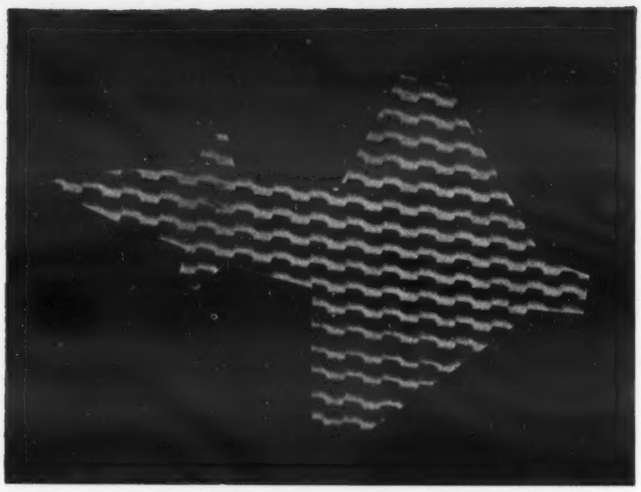

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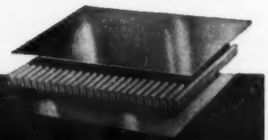

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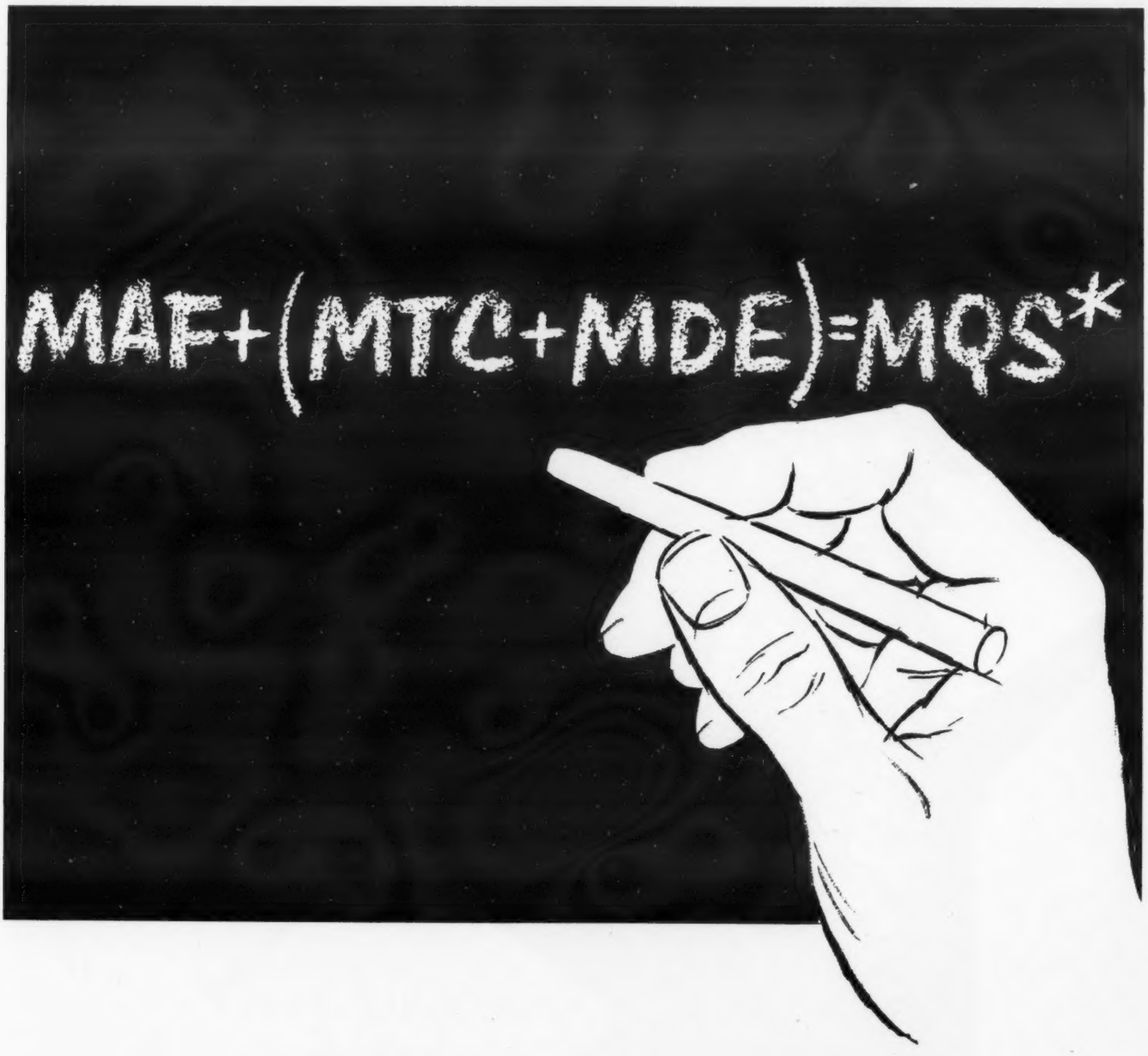

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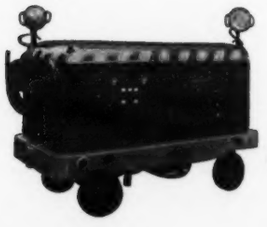

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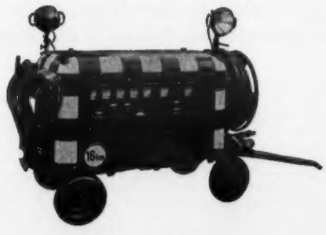

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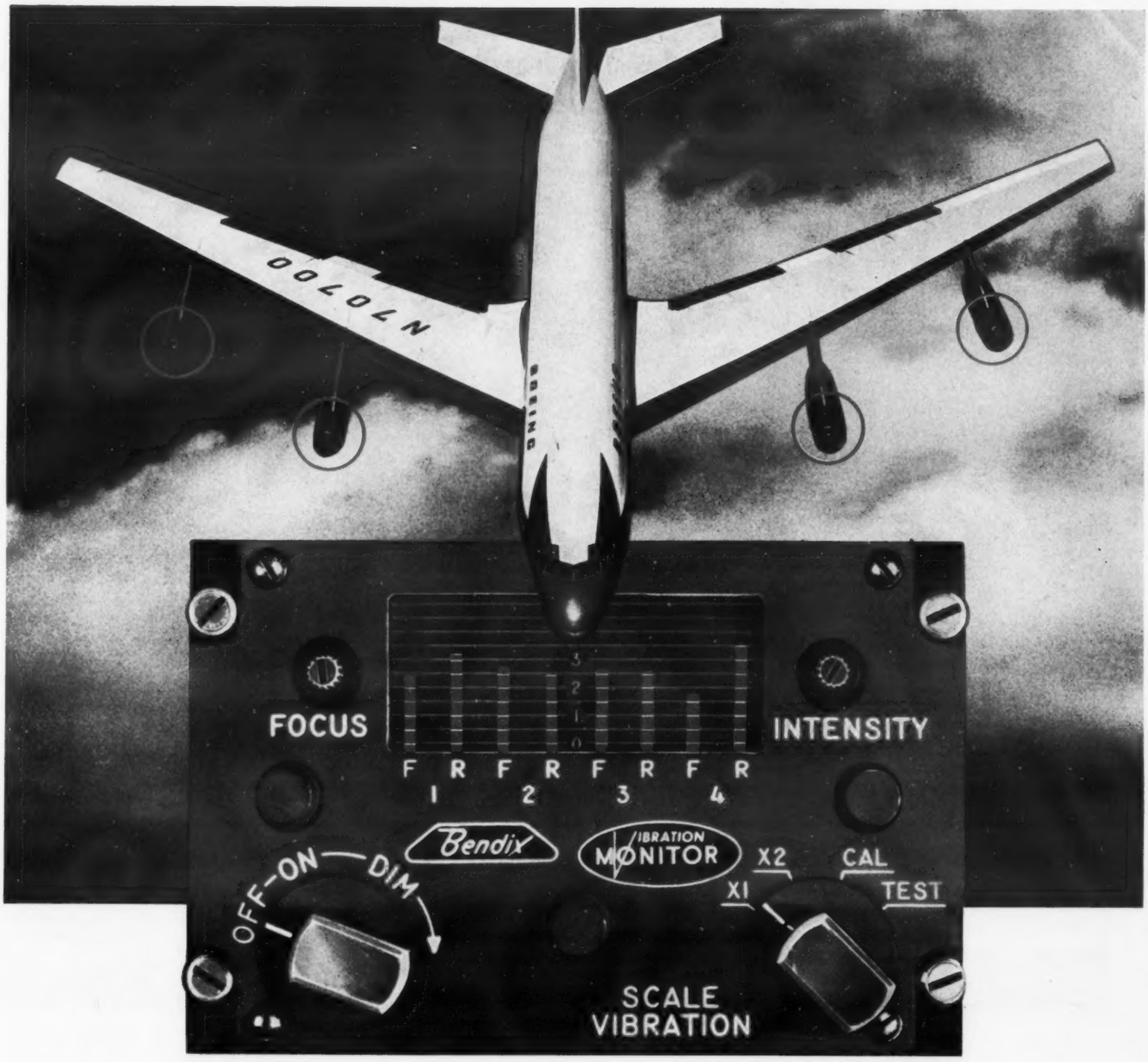

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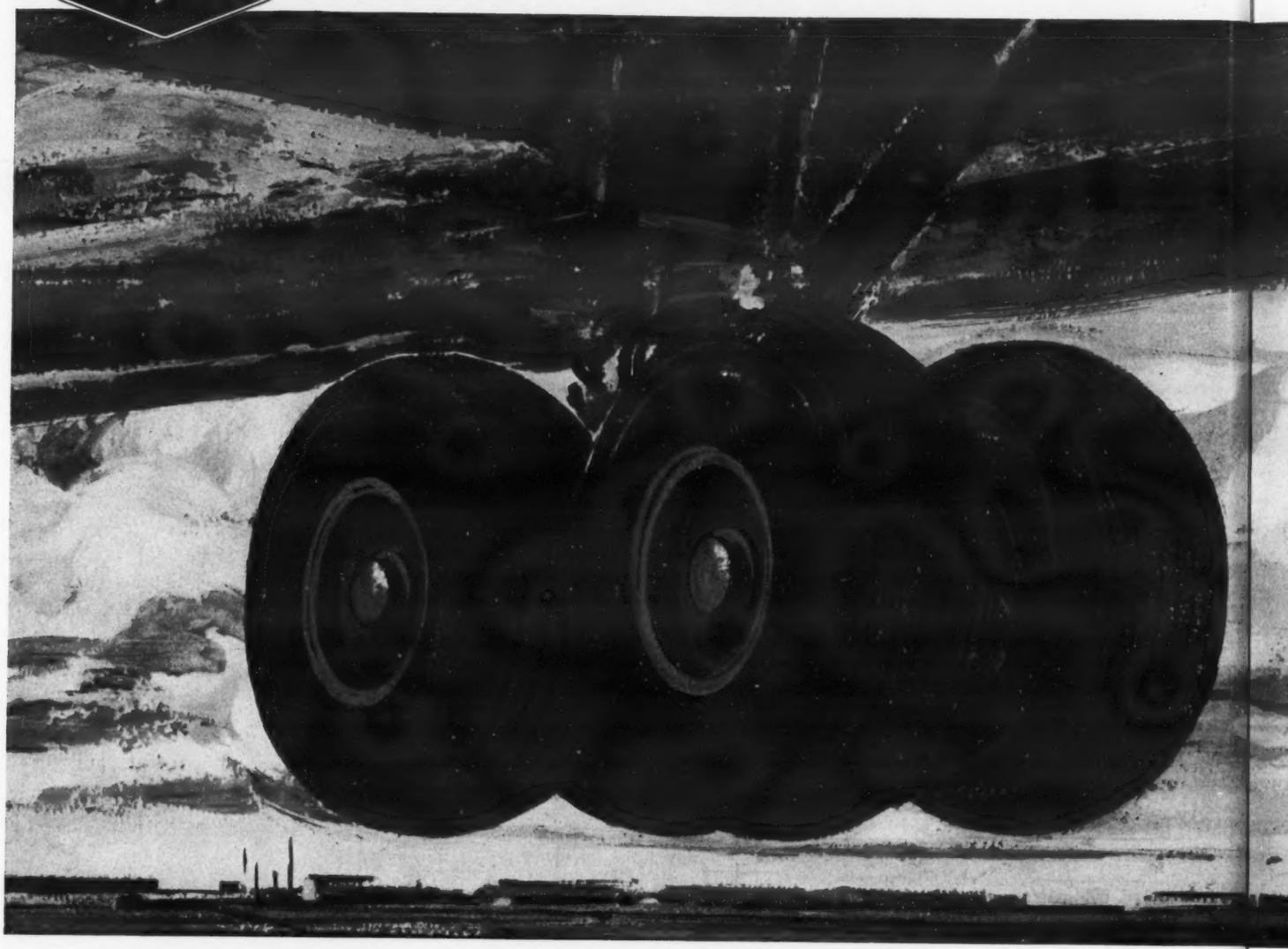

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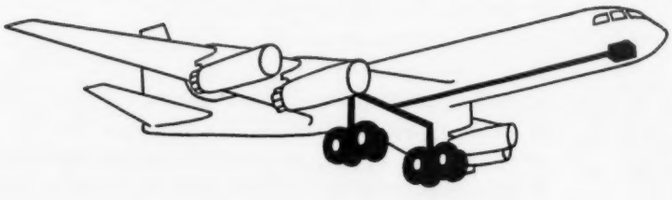
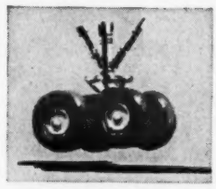
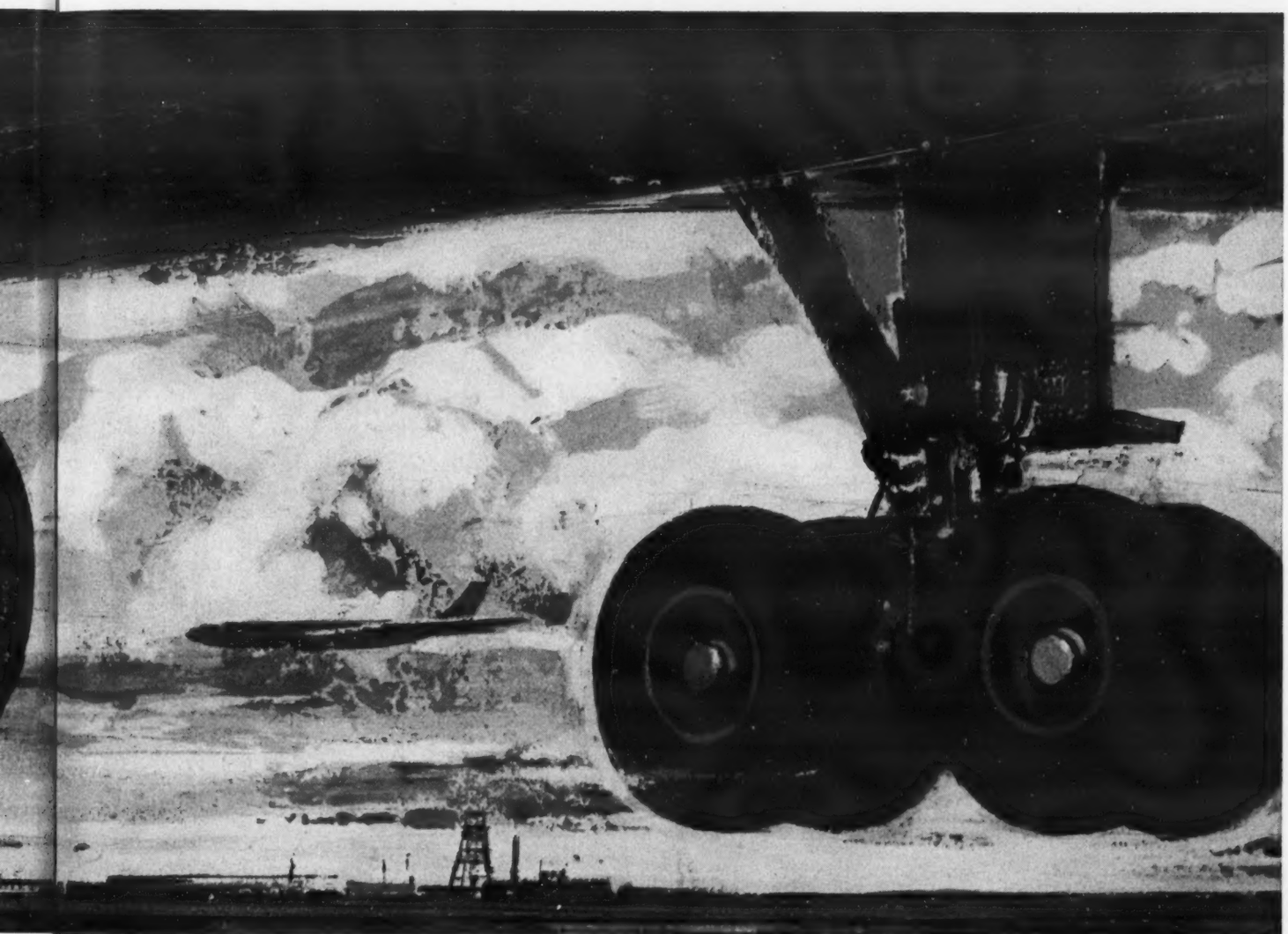




WANTED: A tire to accelerate from zero to 200 m.p.h. in seconds – 155 tons of airplane entrusted to its tires until airborne. Tire must also cushion the landing impact on to a rock-hard runway and bring the tremendous weight to a smooth, safe halt.

The tire that got the job was no beginner. It was developed by Goodyear for U.S. jet fighters. Its new, fabric-reinforced tread withstands the stresses of high-speed take-offs and landings. Now giant jets the world over depend on Goodyear aircraft tires to take the great mechanical strains of modern flying.



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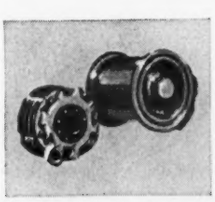
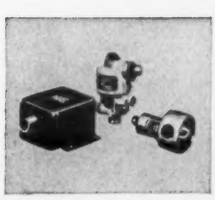


WANTED: Wheels and brakes to carry and stop the equivalent load of several trailer trucks moving faster than any sports car. No margin for errors —efficiency at all times an absolute must.

Goodyear, with 20 years aviation experience, got the job with Tri-Metallic Brakes and Forged Aluminum Wheels, designed for high-speed, heavy-load jets. Today, as yesterday, more commercial airliners rely on Goodyear wheels and brakes than all other makes combined.



WANTED: A brake control device that thinks and acts with the speed of lightning. Device must sense skid tendencies—and at speeds up to 275 m.p.h. It must react instantly to prevent wheel lock-up. With anti-skid, the brake can take advantage of the full tire coefficient and produce the shortest possible stopping distance.

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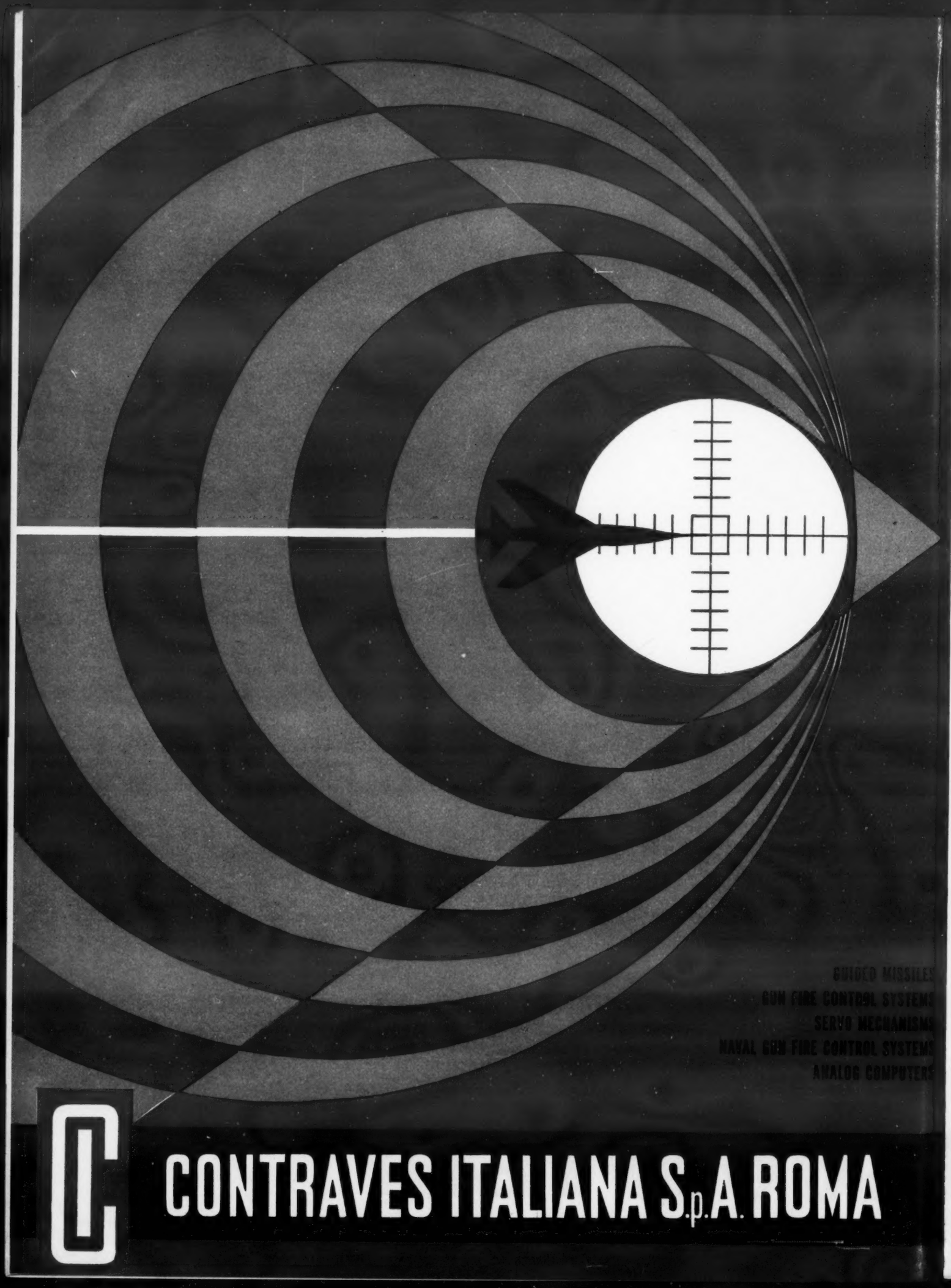

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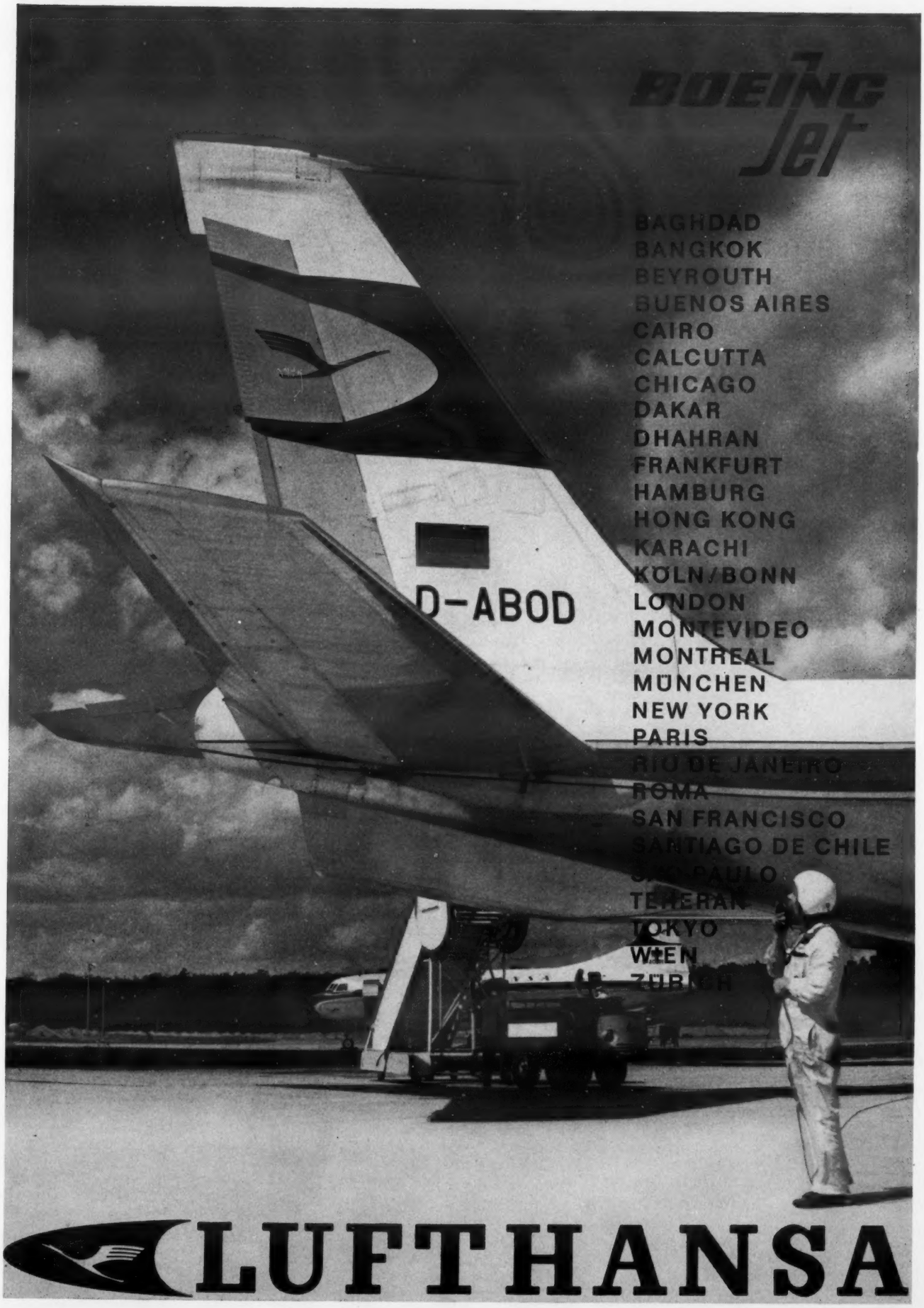
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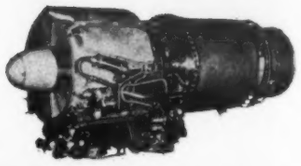

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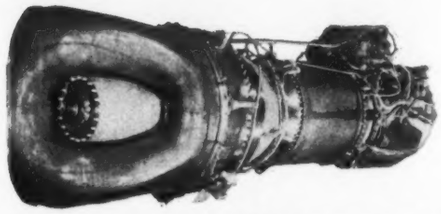
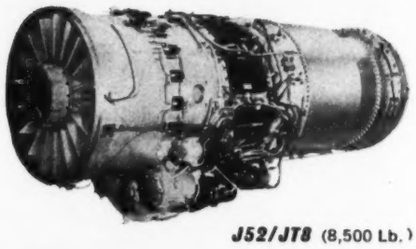
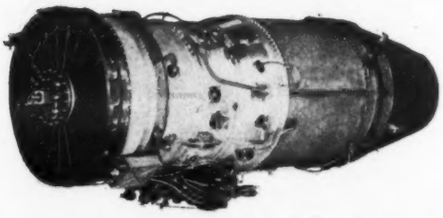


JFTD-12 (4,050 Shaft HP)

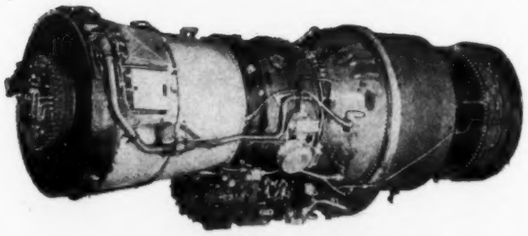


J52/JT8 (8,500 Lb.)

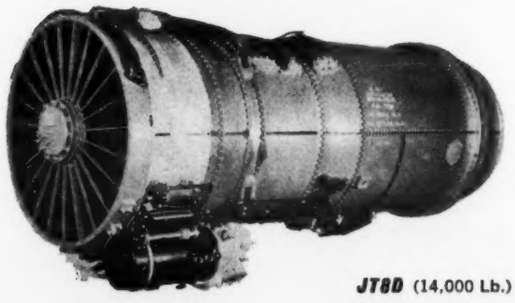


JTF10 (10,000 Lb.)

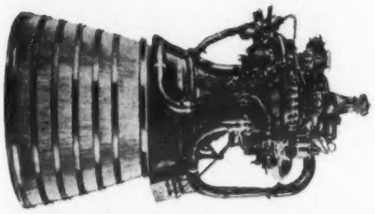
Power



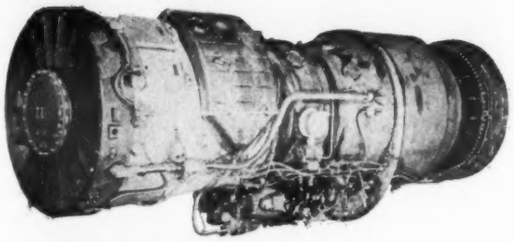
J57/JT3C SERIES (12,000-13,500 Lb.)



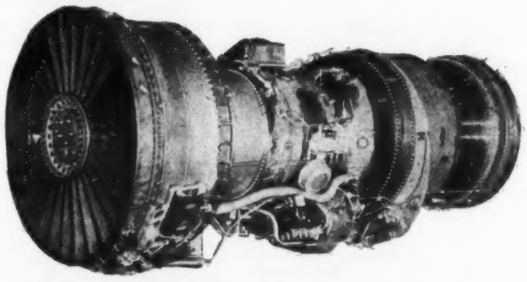
JT8D (14,000 Lb.)



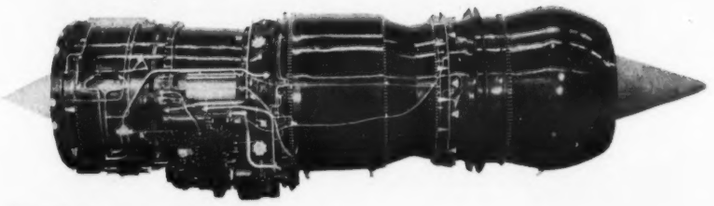
LIQUID HYDROGEN ROCKET ENGINE LR-115 (15,000 Lb.)



J75/JT4A (16,800-17,500 Lb.)



TF33/JT3D SERIES (17,000-18,000 Lb.)



J58/JT11 (30,000 Lb. class)

that spans the field of flight

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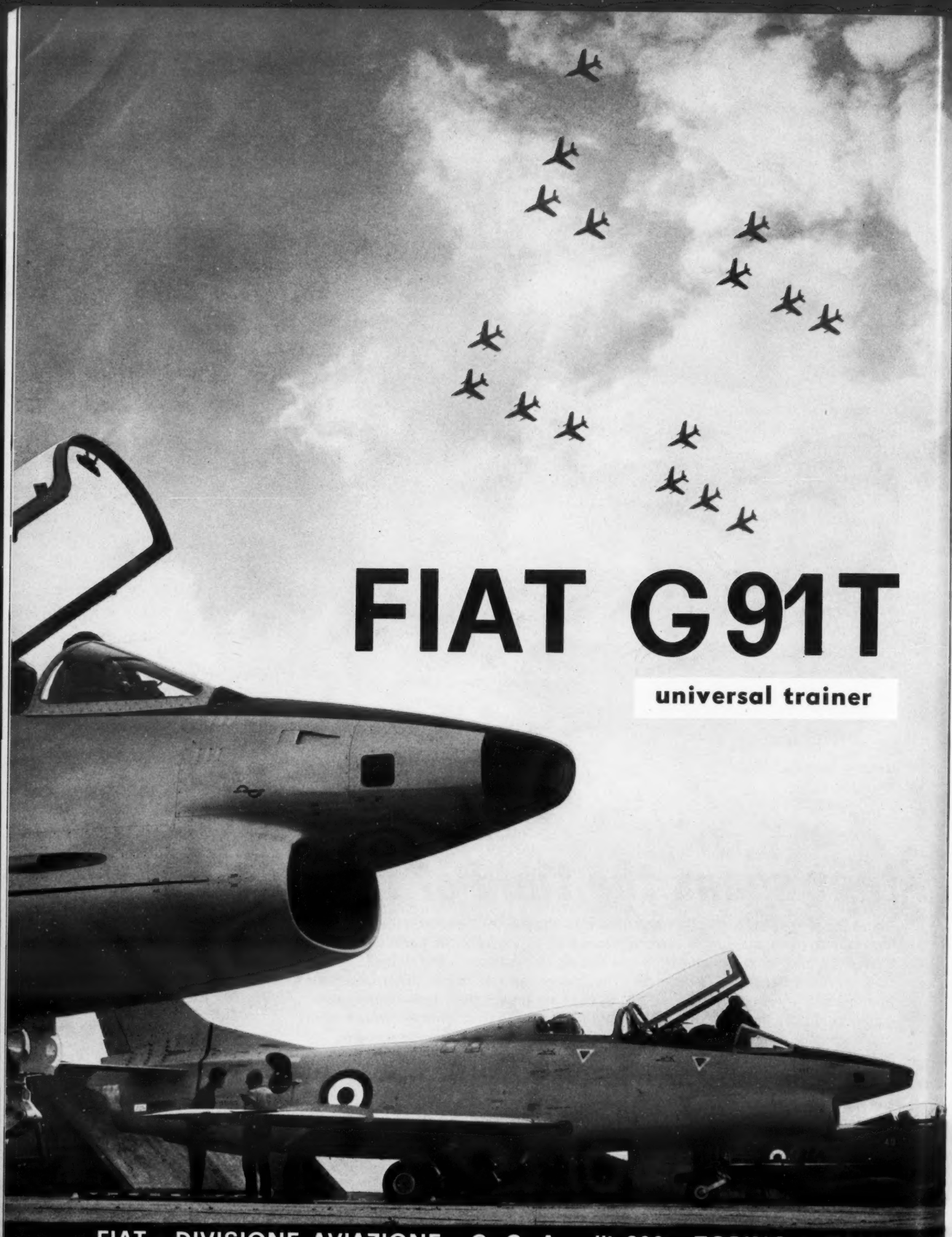

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Saladin Armoured Car

Saracen Armoured Personnel Carrier

Salamader Fire Crash Tender

INTERAVIA AIR LETTER reports ...*

Air transportation

US airline managements are reviewing policy changes on passenger service and no-show problems for submission to CAB. Other problems resulting from the September 28th meeting of 13 US trunk carriers with CAB will be taken up later. Recommendations on the no-show problem will probably include changes in reservations procedure, and trunkline operators have CAB permission to meet with eleven local service operators in an effort to find a solution. CAB warns that carriers must accept stiff penalties for overselling if they decide to impose no-show penalties.

Resulting from the September 28th meeting, CAB is to establish principles to guide elimination of excessive competition and these may take the form of mergers, route exchanges, or adjustments (the New York-Washington route now operated by eight carriers is a good example). CAB is also reviewing international competition policies and may take emergency measures to assist US carriers whose traffic is declining (the US share was down from 74.7 percent in 1950 to 54.7 percent in 1960). Chairman Alan S. Boyd said that CAB was unable to enforce provisions of US air agreements, but foreign countries were imposing restrictions on US carriers. CAB is cooperating with the Department of Justice to decide whether pool arrangements by US carriers would violate anti-trust laws, previously frowned upon by CAB as inhibiting competition.

●

The Canadian Government has filed suits against Pan American World Airways and KLM Royal Dutch Airlines to recover overflight charges totalling $736,068 ($64 for use of navigational facilities plus $20 for radio contact on overflight of Canadian territory). Following threat of action in March, eight other US and European carriers settled outstanding claims totalling some $1.3 million.

●

The UK Air Transport Licensing Board is to adopt a stricter approach to licensing decisions, particularly regarding IT operators, according to the first report issued last month. ATLB is carrying out a thorough investigation of the financial standing of all operators and will also insist that insurance cover is adequate. The Board will clamp down on IT operators anticipating licence awards by taking advance bookings for the service applied for, and recommends that IT organizers should name the operators involved (and possibly aircraft used) in publicity material. The Board is currently studying some 600 applications for charter flight licences for summer 1962, and rejection of these applications could virtually kill a small independent operator overnight. Investigation of financial resources is likely to result in rejection of several applications.

●

Alitalia carried 67,027 passengers on the North Atlantic route during the first nine months of 1961 (up 58 percent on 1960), with September passenger volume at a record 11,123 (up 33 percent on September 1960). However, a 100 percent increase in capacity over last year brought the nine-month load factor down from 67 to 52 percent. October eastbound advance bookings were up 67 percent on the previous year, largely due to 17-day excursion rates.

●

Panair do Brasil has ordered four *Caravelle VIs* and taken an option on two more. Deliveries in April (1), May (1), and June (2) 1962, and the two optional aircraft probably in 1963. The formal contract also includes a letter of intent covering three supersonic *Super Caravelles*. Douglas Aircraft negotiated the deal.

●

Cathay Pacific Airways has ordered a Convair 880 for delivery early 1962 to meet jet competition which has forced withdrawal of the carrier's recently-reinstated *Britannia* nonstop service Hong Kong-Tokyo. Pilot training will be handled at San Diego.

●

Air Afrique, the Ivory Coast-based operating company formed by former French Community African States, inaugurated first scheduled international service Paris-Port Etienne - Dakar - Abidjan - Contonou - Douala on October 16th with a *Super Constellation* on charter from Air France, and on the Paris - Nice - Douala - Libreville - Port Gentil route on October 19th with a Douglas DC-6 leased from UAT. Initial frequency is once-weekly on both routes. Air Afrique also has fourteen DC-4s on charter from Air France and UAT, and will rely on these aircraft until direct purchase of modern jet equipment has been decided. Turnover for 1962 is forecast at NF 100 million ($20 m).

●

West Germany and Morocco signed a civil aviation agreement in October governing traffic between and through the two countries.

Air Ceylon has concluded a pooling agreement with Indian Airlines Corporation and plans to lease *Viscounts* (one or two) from IAC for regional services. The carrier also plans expansion of service in India and to Rangoon, and agreement has been reached with the Burmese Government. BOAC is also operating once-weekly *Comet 4* service on charter to Air Ceylon from April 1962.

●

Saudi Arabia has approached the Swiss Government regarding operation and management of Dhahran Airport when US Forces withdraw shortly. Early reports indicate that Swissair may undertake ground handling, with International Aeradio Ltd. operating and maintaining radio, nav-aids and ATC. Saudi Arabian Government asked for tenders for this work in August.

Industry

British Aircraft Corporation has booked an order from Braniff International Airways for six BAC.111 short-haul jets, with an option on a further six. Total value of the twelve aircraft, plus spares, is approximately $35 million. Delivery of the first six will begin October 1964 and continue through first quarter 1965. Middle East Airlines is also negotiating with BAC on a possible order for twelve BAC.111s. Last May British United Airways ordered ten BAC.111s and took an option on a further five.

●

Major sub-contractors for components of the Lockheed C-141 jet cargo aircraft are: GD/Convair—$6.5 million for tail units; Bendix (South Bend, Ind.)—$600,000 for main landing gear; and Cleveland Pneumatic Co.—$465,000 for nose landing gear. These sub-contracts cover component production for the first five C-141s. Lockheed's contract for the C-141 specifies at least 50 percent sub-contracting. First roll-out of the turbofan-powered C-141 is scheduled for August 1963, with first flight in November.

●

North American Aviation's Autonetics Division has received a $12.5 million contract from International Business Machines Corp. in connection with the USAF's B-52 modernization programme. The contract covers orders issued over the past eighteen months for production of terrain-avoidance computers (part of the IBM bombing-navigation system), test controls, and auxiliary equipment.

A scale model of a heavy assault transport helicopter proposed for military use by Sikorsky Aircraft and suitable for carrier operation. The new model utilizes main and tail rotors and transmission system from the S-64 *Skycrane*. Maximum payload is quoted as up to 9 tons for short ranges. Features include: watertight hull; rear-loading cabin; hydraulically-operated ramp; retractable tricycle undercarriage; automatic blade and tail folding systems; high-speed, heavy-duty cargo handling system; automatic external cargo pick-up probe; all-weather operation; self-sealing fuel tanks in external sponsons. A 60-passenger airline version for civil use has the designation S-65.

* " Interavia Air Letter " is a daily international news digest for specialist circulation, published in English, French (" Courrier Aérien "), and German (" Luftpost "). All rights reserved.

First German-built Fiat G.91 and Lockheed F-104G fighters were handed over to the West German Air Force on October 16th. This F-104G was the first to be built from scratch in West Germany (with US-supplied material) and made its first flight on October 5th. Arge 104 Süd (Dornier, Heinkel, Messerschmitt and Siebel) will build 210 F-104Gs for the West German Air Force. The Dornier-Messerschmitt Group is building a total of 296 Fiat G.91s under licence.

●

Matra R.530 air-to-air missile development and testing is now at an advanced stage and the weapon has been selected by the French Air Force to equip the Dassault *Mirage III*. The Matra 530 is also being offered to various European NATO forces. Speed is reportedly about Mach 2.2, and the weapon is offered with either semi-passive automatic homing head or with infra-red guidance.

●

The Morane-Saulnier company celebrated its 50th Anniversary last month. In this half century, under the guidance of President Raymond Saulnier, the company has developed some 70 aircraft types and total production is over 7,500 aircraft. The current programme includes the four-place twin-jet MS.760 *Paris* and the three-place MS.880 *Rallye*.

●

Zonta International, a service organization of business and professional women executives, will accept applications up to February 15th, 1962 from qualified candidates for grants of $2,500 in the 1962-63 school year for graduate study in aeronautical sciences. Applicants must hold a bachelor's degree in a science acceptable as preparatory for advanced aeronautical studies in an approved college of their own choice. Chairman of the Amelia Earhart Scholarship Committee is Dr. Helen Pearce, 490 Oak Street S.E., Salem, Oregon.

Military affairs

The French Air Force is apparently interested in acquiring a batch of Lockheed C-130Bs to equip a Tactical Heavy Transport Group. In October the French Government reportedly approached the US Government with a view to leasing or "borrowing" some 15 aircraft, but apparently met with little success. Latest unofficial information available as this issue went to press was that the Government was preparing to negotiate direct with Lockheed to purchase the aircraft, probably for assembly in France. No official statement had at that time been released by either the French Government or Lockheed. French aviation circles welcome the decision to set up a Heavy Transport Group, but have expressed considerable concern regarding the proposed procurement of American aircraft for this task.

●

Interest in the medium-range ballistic missile (MRBM) has been stepped up with reports that the project will be funded for development in fiscal 1963. The USAF has had some form of MRBM listed as Specified Operational Requirement 161 since 1957, and the US Army would like to see its extended-range *Pershing* chosen. A Tactical Air Command spokesman has said that a truck-mounted MRBM with 1,000-1,500 miles range could be ready in the next few years to replace a portion of the Tactical Air Force aircraft overseas. MRBM production and maintenance would be cheaper than the aircraft it would replace. Required characteristics are truck mobility over secondary roads, quick reaction capability, low CEP, solid or storable liquid propellant, and operation with a three-five-man crew. Development of an effective command system for the control of a widely-dispersed MRBM force would be a major problem.

●

The US Navy is requesting proposals for an off-the-shelf four-place turbine-powered helicopter capable of carrying an 800 lb payload over a 50 n.m. radius at a cruising speed of 85 knots to replace Kaman HOK helicopters and Cessna OE fixed-wing aircraft now in service with the Marine Corps. The Navy specifies minimum casualty evacuation capability of two internal litters and will consider modifications of existing models. Proposed helicopters must be available for evaluation in 1963 and delivery in quantity as soon as possible thereafter.

●

General Silvio Napoli, former Chief of Staff of the Italian Air Force, died on October 14th. General Napoli had submitted his resignation on health grounds in September.

●

The Royal Rhodesian Air Force has given Sud-Aviation an order for five *Alouette III* helicopters. The RRAF order follows a recent South African Air Force contract for an undisclosed number (reportedly 50) *Alouettes*.

Aircraft and powerplant

Sud-Aviation plans to equip the Sikorsky S-58 helicopter with a Turboméca *Twin Bastan* shaft turbine unit replacing the present 1,525 h.p. Curtiss-Wright R-1820-84 piston engine. This unit would have a continuous rating of 1,700 h.p. and a cruise rating of 1,475 h.p. Equipped with the *Twin Bastan*, the S-58 would have an AUW of 6,030 kg (13,290 lb) and a useful load of 2,390 kg (5,270 lb); cruise speed approximately 85 knots (160 km/h); maximum range 215 n.m. (400 km); service ceiling 11,500 ft (3,500 m) at normal operation and 9,200 ft (2,800 m) at 22°C. Turboméca is scheduled to complete the first *Twin Bastan* this month.

●

Hispano Aviación's HA-56 design project is intended as a pre-prototype for development of a projected model HA-230 twin-jet executive aircraft. The HA-56 is a low-wing monoplane with pressurized cabin and retractable nosewheel gear. Powerplant will probably be two 1,540 lb (700 kp) thrust bypass engines currently under development by Turboméca. Empty weight 3,860 lb (1,750 kg); maximum all-up weight 8,380 lb (3,800 kg); maximum landing weight 6,610 lb (3,000 kg). Average cruise speed 370 knots (680 km/h) at 29,500 ft (9,000 m).

●

The Douglas DC-8F Jet Trader combination cargo/passenger transport will be able to lift over 94,000 lb in the all-cargo configuration and can be rapidly converted to a 183-passenger configuration. Four different intermediate passenger/cargo configurations are also possible. On a typical long-range international route, the *Jet Trader* can profitably carry cargo for 15 U.S. cents per ton-mile. Passenger rates could be reduced by as much as 20 percent in low current economy tariffs. Nonstop range 5,000 st. miles with 50,000 lb payload and cruise speed of over 575 m.p.h. Total cargo volume 9,205 cu.ft. Maximum take-off weight 315,000 lb.

●

Republic Aviation Corp. has demonstrated a plasma engine for use in space vehicles and a flyable prototype should be completed by beginning-1962. The Republic engine uses a heavy gas as fuel, which is ionized after injection. It is then accelerated electromagnetically and subsequently ejected at ultra-high speeds. Ejection speeds of over 99,360 m.p.h. (160,000 km/h) have already been recorded during tests.

●

Rolls-Royce started flight testing the *Spey* by-pass jet engine in October with two units mounted on an Avro *Vulcan* bomber in the inboard engine positions. *Spey* engines are specified for the BAC.111 and the de Havilland DH.121 *Trident*. Work is going ahead on a military version for the Blackburn *Buccaneer* S.2 strike aircraft.

●

Beech Aircraft Corp.'s new 1962 four-seat Model B33 *Debonair* features increased cruise range, increased fuel capacity (80 U.S. gal) and an improved cabin layout. Powered by a 225-h.p. Continental 10-470-K engine, the *Debonair* is offered at a basic price of $21,975.

●

Piper Aircraft will market the *Apache* H-model in 1962. The new "H" version is powered by two 160-h.p. Lycoming engines, has a cruising speed of 171 m.p.h. (275 km/h), and a maximum range of 1,250 miles (2,010 km). Provision has been made for factory installation of more comprehensive navigation and communications equipment (including DME).

●

Morane-Saulnier is reportedly working on a twin-jet, 6-10-place executive aircraft design. Powerplant will probably be either Pratt & Whitney JT12s (3,000 lb thrust) or Turboméca units (1,700-2,000 lb thrust) derived from the *Bastan*.

●

Sud-Aviation is offering several versions of the *Caravelle 10*. These are the 10A (as ordered for TWA) with extended fuselage; 10B with Pratt & Whitney JT8Ds; 10BF also with P&W powerplants but with normal fuselage; 10C high-density seating version (maximum 99 passengers); and the 10D with Rolls-Royce RB.174 powerplants to meet any possible British orders. The *Caravelle 10A* for TWA will have a 39-inch longer forward fuselage and a cabin layout for 68-69 passengers; advanced wing leading-edge fillet to give increased sweep and reduced thickness-to-chord ratio. These modifications will permit increase of maximum permitted speed from Mach 0.77 to 0.81. Normal *Caravelle* flaps will be replaced with double-slotted flaps and spoilers, cutting landing distance by 1,000 ft compared with the *Caravelle 6R*.

●

The Kurir multi-purpose aircraft, built by the Ikarus works in Yugoslavia, is designed to carry a maximum of three passengers or 660 lb (300 kg) payload. Powerplant is one downrated 155 h.p. DM 6R piston engine with two-blade Scintex VP propeller. The *Kurir* is a cantilever shoulder-wing design with light metal wing construction. Fabric-covered welded steel tube fuselage. Fixed conventional undercarriage and conventional tailplane. Span 46.1 ft; length 31.9 ft; wing area 267 sq.ft with large area flaps. Maximum take-off weight 3,200 lb; maximum useful load 1,210 lb. Maximum speed 112 m.p.h. Service ceiling 12,470 ft. Range 500 n.m.

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The Westland range of turbine powered helicopters covers rotary wing aircraft from 5000 lb. to 58000 lb. which are capable of meeting all requirements in all parts of the World.

Advantages of turbine powered helicopters include improved overall operating economy, less noise and vibration and greatly improved performance in high temperatures and at high altitudes.

Westland were among the pioneers in the application of turbine power to the helicopter and already in this class they have in production the Wessex I, Wessex II, Gnome Whirlwind, Belvedere, and the Scout, whilst the development of the 60/65 seat Rotodyne vertical take-off airliner is actively progressing.

Westland Helicopters are in service with the following:—

Governments of Ceylon, Cuba, Egypt, Iran, Iraq, Kuwait, Hong Kong, France, Thailand, Yugoslavia, Japanese Security Forces, Brazilian Navy, Royal Jordanian Air Force, Ghana Air Force, Royal Navy, British Army, Royal Air Force.

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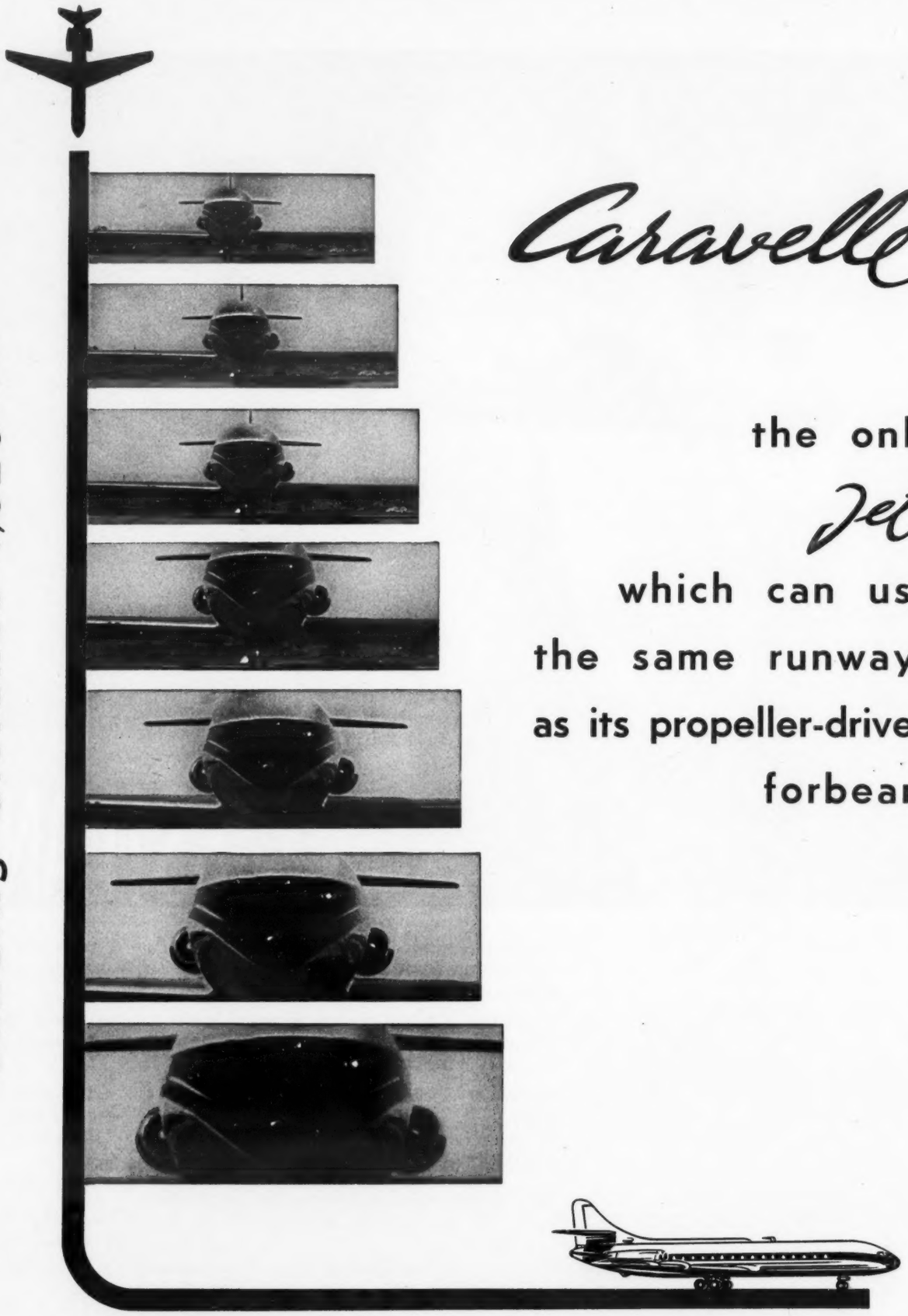

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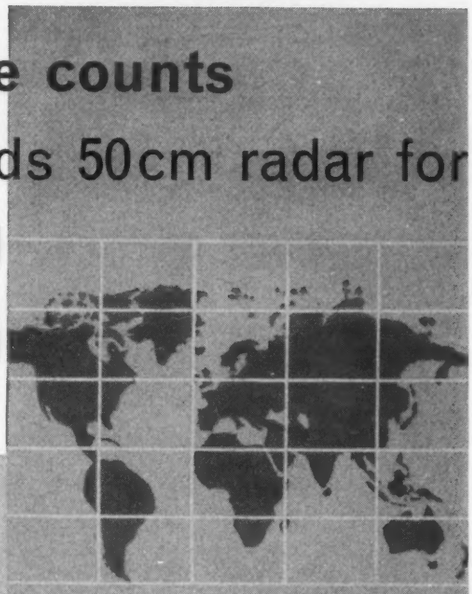

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BRISTOL/FERRANTI

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Bloodhound Mark 2 is a second-generation missile system and is the logical development from Bloodhound Mark I.

Bloodhound Mark 2 has:

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Bloodhound system management by Bristol Aircraft Ltd. Radars and electronics by A.E.I. Ltd. and Ferranti Ltd.

BRISTOL/FERRANTI

BLOODHOUND

MARK 2

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miniature inertial components.

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variable geometry provides the answer

In the Fokker Republic V.T.O.L. Development Division the inherent problem of combining vertical take-off and landing with supersonic speeds at sea level and at high altitude has been resolved through use of advanced aerodynamics: variable geometry wing.

The revolutionary Fokker-Republic V.T.O.L. aircraft which is in final development stage, incorporates variable-sweep wing design with a single lift and thrust engine. It is so designed that it has the versatility for vertical *or* short take-off —flies to its target at high or low altitudes at supersonic speed with its wings folded—or wings extended at subsonic speeds for considerably greater distances. Thus this versatile strike/reconnaissance aircraft combines the tactical advantages of V.T.O.L./S.T.O.L. with all-weather supersonic performances.

Multi-million research programmes have been carried out, at first independently, now jointly by Fokker and Republic. The final design is the culmination of five million dollars, seven years of engineering man-hours, wind-tunnel testing, data reduction, and close liaison with the engine manufacturers, the Bristol-Siddeley Company.

V.T.O.L. . . . S.T.O.L. . . . wherever aviation takes on new directions, Fokker-Republic lead the field.

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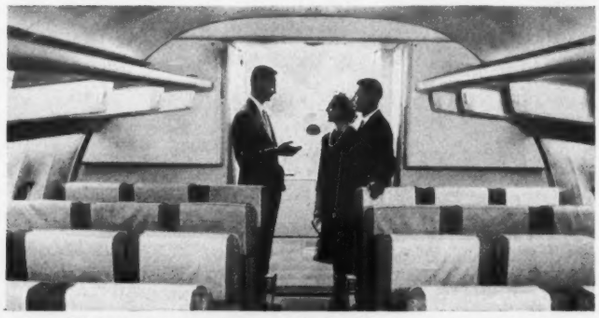
Preview of the new short-range Boeing 727

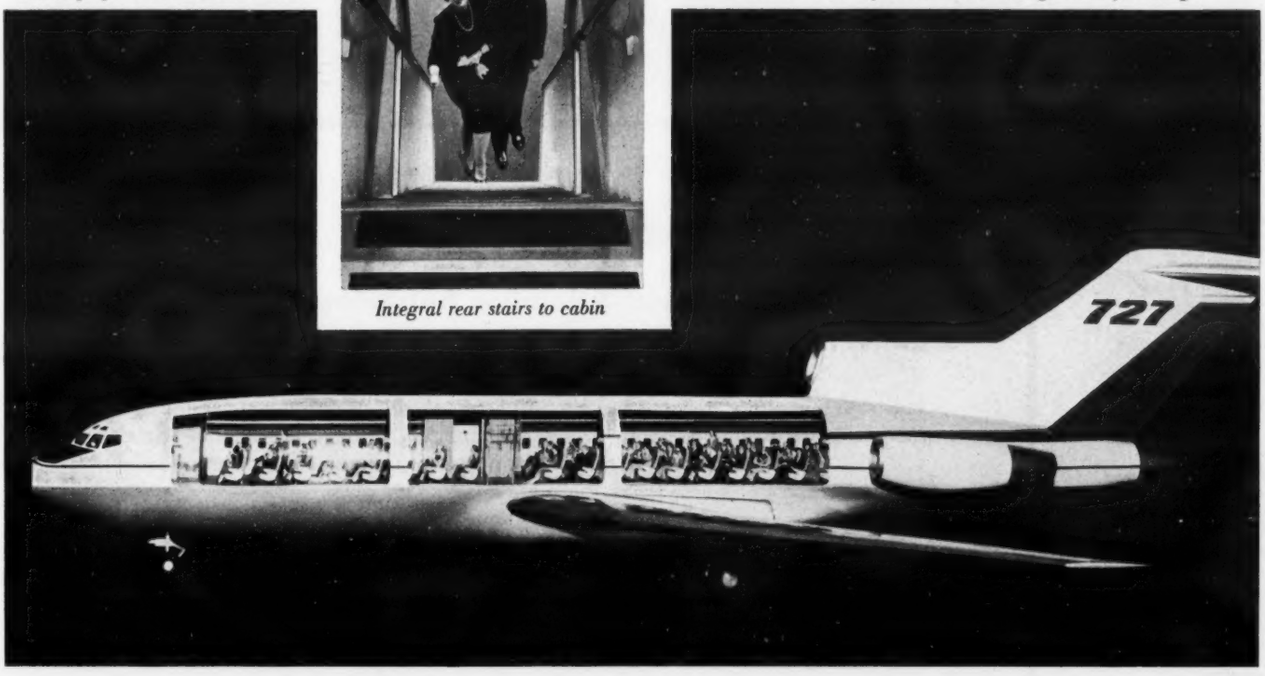
727 has 3 rear-mounted engines

Mock-up of 1st class cabin section

Integral rear stairs to cabin



Wide 727 cabin permits 6-abreast high-density seating



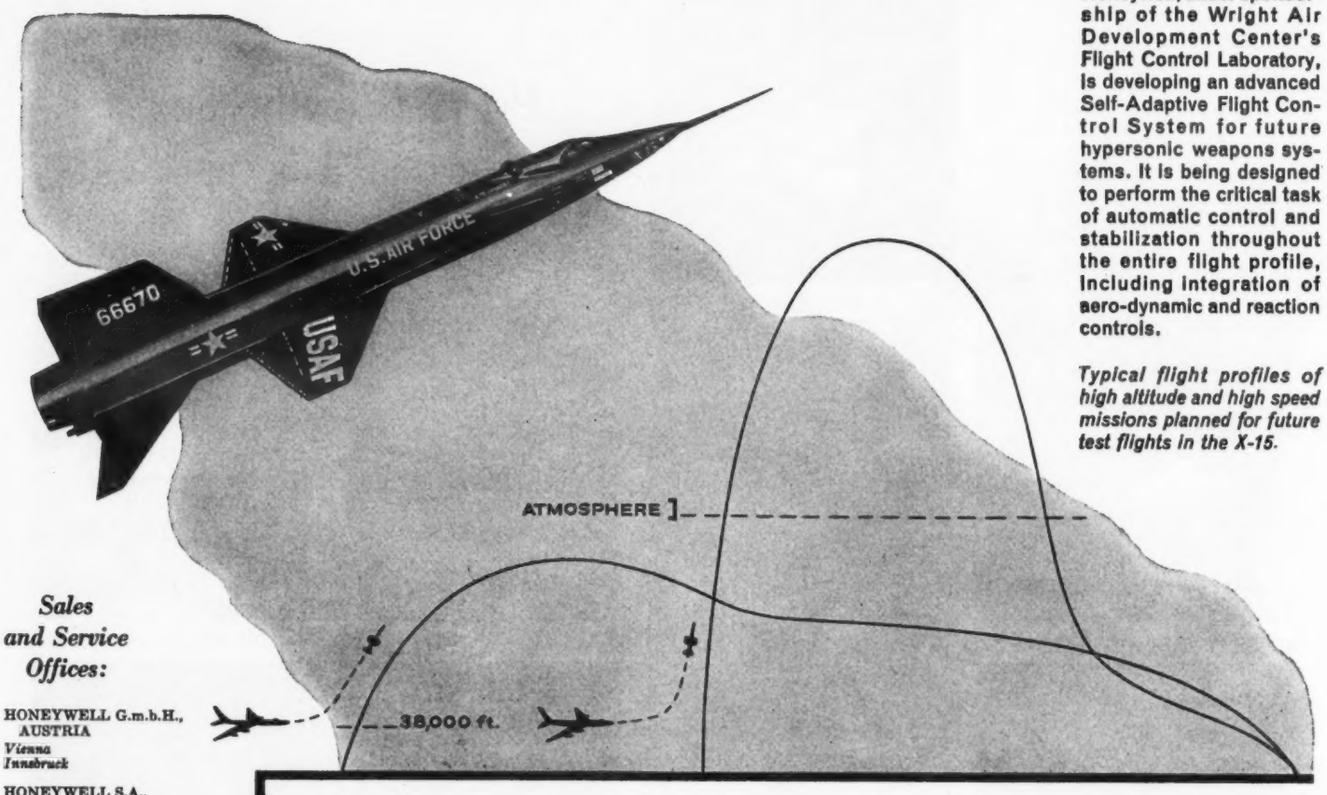
Shown above are photos of scale models and a full-size mock-up illustrating some of the outstanding features of the new Boeing 727 short-range jetliner.

Designed to produce an operating profit even at modest load factors, the 727 is a high-performance jet that will service 150- to 1700-mile routes, operating from 5000 foot runways with full payload.

The 727 brings airlines many short-route features, including quick takeoff, rapid climb to cruise altitude, low approach speed, the durability required for frequent takeoffs and landings, and integral airborne stairs to help reduce ground time during short stops. Capacity ranges from 70 first-class to 113 tourist-class passengers, plus 850 cubic feet of heated and pressurized cargo space. Another unique 727 advantage is the incorporation of many systems and components proved out in more than 350,000,000 miles of Boeing jetliner operations.

Already, American Airlines, Eastern Air Lines, Lufthansa German Airlines and United Air Lines have ordered 117 Boeing 727s for delivery beginning late in 1963.

BOEING 727



Honeywell, under sponsorship of the Wright Air Development Center's Flight Control Laboratory, is developing an advanced Self-Adaptive Flight Control System for future hypersonic weapons systems. It is being designed to perform the critical task of automatic control and stabilization throughout the entire flight profile, including integration of aero-dynamic and reaction controls.

Typical flight profiles of high altitude and high speed missions planned for future test flights in the X-15.

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The Honeywell Self-Adaptive Autopilot is designed to deliver optimum performance for every type of flight vehicle

The simplest, most reliable automatic flight control system yet designed, the Honeywell Self-Adaptive Autopilot operates independently of air data information and complex gain scheduling. Adjusting itself in response to its own performance, it is unaffected by changes in aero-dynamic characteristics. Here are some of its advantages.

Simplicity—Needs no air data information for gain scheduling—is not significantly affected by design modifications in aircraft, asymmetric loading or center of gravity changes—is easily mechanized and needs little tailoring to specific vehicles—is 45% smaller and lighter—requires 50% less power.

Reliability—Provides major reduction in required components, sub-assemblies and wiring—uses solid state amplifiers and switching logics.

Economy—Assures significant cost reductions through low initial cost of design and development, and simplified logistics, training and maintenance.

Versatility—Can be quickly adapted without major modifications to business aircraft, helicopters, drones, supersonic fighters and bombers, missiles and the latest hypersonic research vehicles. The Honeywell Self-Adaptive Autopilot System is now undergoing flight tests in both the supersonic F101A and "light-twin" Cessna 310 aircraft—impressive evidence of its wide range of adaptability. To learn about fitting it into your plans, write Honeywell, International Division, Minneapolis 8, Minnesota, U.S.A.

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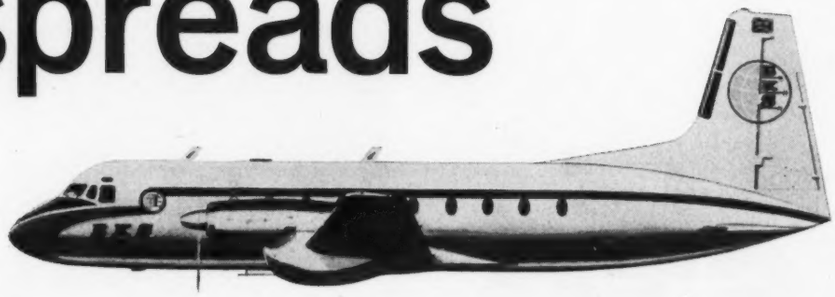

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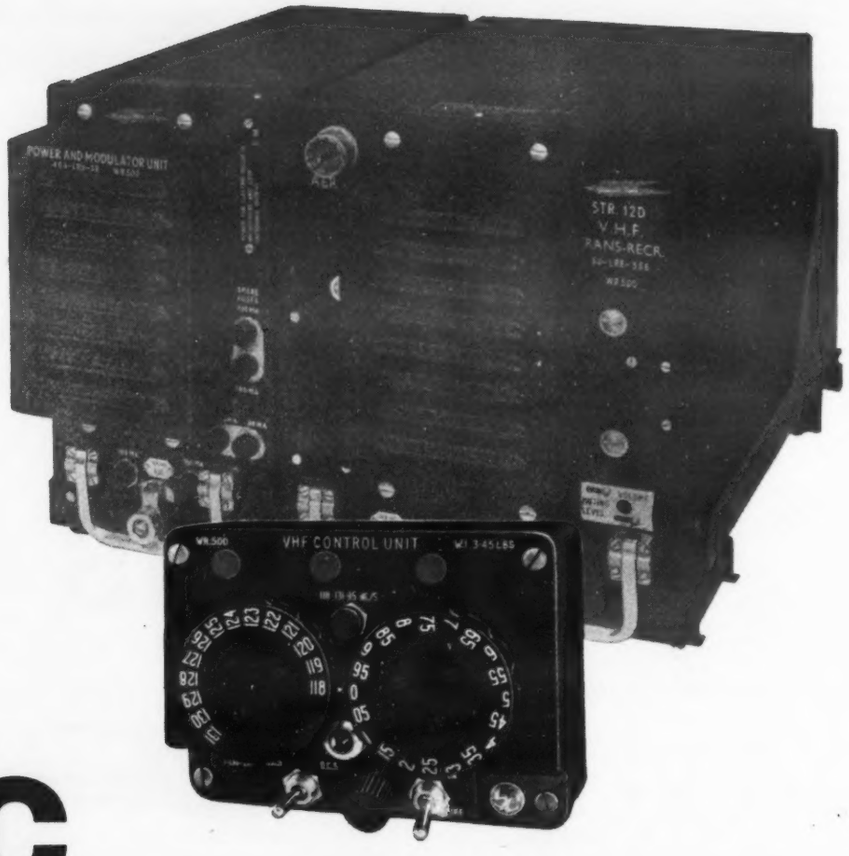

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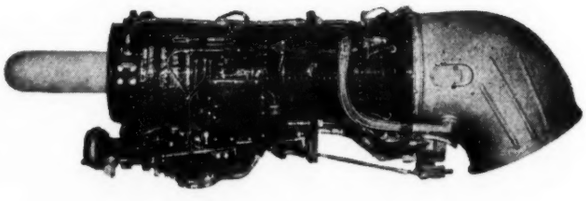

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Nov. 6th-17th : American University : 15th Annual Symposium on Air Transport. Washington, D.C.
Nov. 7th-13th : International Symposium on Numerical Weather Prediction. Tokyo.
Nov. 9th : Institution of Production Engineers : Lecture on Cold Forging. Royal Aeronautical Society, London.
Nov. 10th : British Interplanetary Society : Photography from Rockets and Satellites. Royal Aeronautical Society, London.
Nov. 13th-16th : Flight Safety Foundation : 14th Annual International Air Safety Seminar. Theme : International Co-operation in Air Safety. Naples.
Nov. 13th-16th : Institute of Radio Engineers : 7th Annual Conference on Magnetics and Magnetic Materials. Hotel Westward Ho, Phoenix, Ariz.
Nov. 13th-18th : Second Engineering Materials and Design Exhibition. Earl's Court, London.
Nov. 14th : ICAO, Limited EUM Frequency Assignment (VHF) Planning Meeting. Paris.
Nov. 14th : ICAO, South American-South Atlantic RAC/COM Meeting. Lima.
Nov. 14th : Institute of Radio Engineers : Symposium on Electronic Systems Reliability. Linda Hall Library Auditorium, Kansas City, Mo.
Nov. 14th-20th : International Congress of the Aerospace Sciences. Miami Beach, Fla.
Nov. 16th : Institution of Production Engineers : The Russian Approach to Production. Grand Hotel, Leicester.
Nov. 21st-24th : AGARD, Flight Mechanics Panel Meeting. Paris.
Nov. 22nd-27th : Fifth Conference and Exhibition on Automation and Instrumentation. Milan.
Nov. 28th-30th : Aviation Distributors and Manufacturers Association : 38th Annual Meeting. Jung Hotel, New Orleans, La.
Nov. 29th : Society of Environmental Engineers : The Response of Dynamic Systems to Shock Excitation. Imperial College, London.
Nov. 30th : Guild of Air Pilots and Air Navigators : Annual General Meeting. Innholders Hall, London.
Nov. 30th-Dec. 1st : Institution of Electrical Engineers : Nuclear Electronics Symposium. Savoy Place, London.
Nov. 30th-Dec. 1st : Institute of Radio Engineers : PGVC Conference. Hotel Radiosson Minneapolis, Minn.
Dec. 2nd : British Interplanetary Society : International Law Extra-Terrestrially Applied. University College, London.
Dec. 5th-6th : FAA : Supersonic Transport Conference. Washington, D.C.
Dec. 5th-7th : National Air Transport Association Meeting. Washington, D.C.
Dec. 5th-7th : National Aviation Trades Association : Annual Convention. Statler-Hilton Hotel, Washington, D.C.
Dec. 6th-8th : National Air Taxi Conference : Annual Meeting. Baltimore Hotel, Oklahoma City, Okla.

1962

Feb. 16th-20th : International Radio and Electronic Components Exhibition. Paris.
March 26th-29th : Institute of Radio Engineers : International Convention. Coliseum and Waldorf Astoria Hotel, New York.
April 28th-May 9th : 35th Brussels International Fair.
April 29th-May 8th : BDLI West German Air Show and Trade Fair. Hanover-Langenhagen Airport.
May 8th-18th : Mechanical Handling Exhibition. Earl's Court, London.
May 24th-June 3rd : 1st International Air Show. Turin.

(The Editors cannot be held responsible for any errors or omissions).

Civil Aviation in France

After the preceding article, which covered Sir William Hildred's diagnosis of the troubles of world air transport, it may be of interest to take a look at the endeavours one of the leading aviation powers is making to develop its air transport.

Finance

At its autumn session, the French National Assembly approved the 1962 budget for the Ministry of Public Works and Transport. The allocation for civil aviation comprises: NF 388,761,000 (about $78,000,000) for current expenditure (previous year NF 345,676,000 or about $69,000,000) and NF 278,000,000 (about $56,000,000) for supplies and equipment (previous year NF 260,990,000 or $52,000,000).

Turning to Air France, the French flag-carrier has ordered four Boeing 707-320B long-haul jet airliners and seven SE.210 *Caravelle* medium-haul jet airliners, which will be delivered in 1963. These included, the Company's total fleet will amount to 24 Boeing 707s and 42 *Caravelles*. 1962 commitments of Air France will amount to NF 368 million (about $74 million) as against NF 262 million (about $52 million) in 1961. Payments to be met during 1962 will amount to NF 360 million (about $72 million), which compares with NF 200 million ($40 million) for 1961, and a loan of part of this amount will be provided by the Fonds de Développement Economique et Social.

The Paris Airport Authority is reckoning on roughly the same expenditure in 1962 as in 1961, i.e. about NF 90 million ($18 million). NF 102 million (about $20,000,000) is allocated for the entire ground organization (infrastructure and development of air routes) inside and outside Metropolitan France.

In the aviation industry sector, the Government has, as is well known, decided to raise the number of *Caravelles* to be built at Sud-Aviation from 150 to 200. Funding totalling NF 128 million (about $26 million) has been provided for 1962 for the prototype development, flight testing, and series production of this model. A further NF 12 million ($2,440,000) has been budgeted for launching series production of the MH.260 *Super Broussard* for use on domestic routes.

Projects

At its session of October 23rd, the French Council of Ministers had on its agenda the future development of air transport and the aviation industry, including the questions of medium-haul supersonic transport, Air Union and Air Inter, but at time of going to press the results of these deliberations are still not available.

As was shown by the Albert Plesman Memorial Lecture recently delivered by Georges Héreil, the opinion held in France is that the *supersonic transport* requires the collaboration of several countries. It is stressed, on the other hand, that France has a certain advantage in the field of supersonic Mach 2.2 transport development owing to the experience gained with the *Caravelle* and *Mirage IV*, and French opinion would therefore find it hard to understand if France were not allotted the part of project leader in any European joint development programme.

As regards the *Air Union*, Air France, Alitalia, Lufthansa and Sabena are reported to have reached agreement on all basic questions, but the French Government, like the other governments concerned, have still to give official approval. It is known that the French authorities are sceptical towards international organisations of this kind; the opponents of Air Union assert that, had Air Union materialised in 1960, this would have cost Air France about NF 100 million this year.

The Council of Ministers finally turned its attention to the *Air Inter* question. It is to be assumed that a loan will be granted to the Company out of the Fonds de Développement Economique et Social, thus putting Air Inter in a position to buy its own aircraft, probably Air France's Vickers *Viscounts*. ↔

Does NATO Really Need the Single-seat VTOL Strike Aircraft?

The expiry date for the submission of design proposals covering the single-seat VTOL strike/reconnaissance aircraft for NATO is drawing near. There is now increasing awareness on the part of both the military planners and the Industry of the outstanding problems and difficulties connected with this project. Apart from purely technical questions, such as prevention of the ingestion of foreign bodies, stabilisation in the vertical phase, ground effects, and pilot safety in the event of engine failure, the main obstacle is still the provision in good time of operational engines of adequate thrust/weight ratio. The level of thrust which can be attained in the foreseeable future is likely to be sufficient for only extremely limited payloads, at any rate when the aircraft is making a vertical take-off. All these difficulties raise the question whether, in its present form, NATO specification NMBR.3, covering the desired VTOL strike aircraft, answers the purpose at all.

It is a fair assumption that the study carried out in the USA by NASA on wings of variable sweep, as well as the plans of the USAF Tactical Air Command for a multi-purpose combat aircraft with STOL characteristics (the TFX study), will have a lasting influence on NATO in its planning of the next generation of combat aircraft. Moreover, the NATO countries participating in licence construction of the F-104 in Europe see themselves confronted with a programme which is likely to occupy them fully until far into the sixties. And the resources to be devoted to this programme make it unlikely that NATO combat aircraft of a new generation can be made available in worthwhile numbers before the end of this decade.

Similar doubts have also apparently been expressed in German Defence Ministry circles, where it was at the same time pointed out that both the F-104G and the G.91 could, if necessary, be converted to short take-off capability. Since, according to unofficial information from certain European aircraft and engine manufacturers, the time set for actually making the projected VTOL combat aircraft available will in any case now be extended, the question arises whether the designs of today will meet the needs of the seventies. Since, in addition, one cannot foresee the future political development in the industrial countries concerned any more than within NATO itself, the whole question needs re-examination. These, at any rate, are the lines on which the arguments of the key military planners run.

Thus, the evaluation of the NMBR.3 submissions by the responsible committees of NATO due to start next year will certainly have some influence on the NMBR.4 specification for a tactical STOL transport to support the VTOL single-seat strike aircraft. There is also a possibility that the December meeting of defence ministers of the NATO powers will lead to complete re-shaping of the procurement policy for military weapon systems, which will also be decisive for the two projects in question. ↔

Jet Transport's Recurrent Problems

From the annual report of Sir William P. Hildred, delivered to the 17th Annual General Meeting of IATA at Sydney.

During the last week in October, the 17th Annual General Meeting of the International Air Transport Association (IATA) took place in Sydney. If the study of the air transport situation which appeared in the October issue of *Interavia* (page 1361) appears to anticipate certain statements from the Director General's annual report made in Sydney, this is only because the facts and figures for 1960 and the first half of 1961 leave no room for any other interpretation.

The "Turbulence Area."

To start with the "results" side of the annual report, Sir William explained that world air transport is going through a period of change-over, the end of which is not yet in view. At this moment, we are half-way through this period of transition to jet transport, and it will be another few years before the airlines have digested their new jet fleets, and all those concerned—airline managements, airport administrations, air transport authorities—will have overcome all the technological and economic difficulties arising from the change, such as maintenance, reservations, traffic control, terminal facilities, and navigation aids. Nevertheless, world air transport should console itself with the thought that these troubles are temporary and that, in the long run, optimism is not out of place.

Traffic Increase

With regard to the figures quoted by the Director General of IATA for the services operated in 1960 (which are based mainly on the ICAO's statistics) we can content ourselves with just a few words, since the differences, as compared with the article published last month, are only minor ones. Of the 106 million passengers carried by the whole world air network*, 23 million were accounted for by international and 83 million by domestic services, figures which show how much attention must be paid to increasing domestic, i.e. especially short- and medium-haul transport. Domestic services carried 1,160,000,000 tonne-kms of cargo, as against international transport's 1,020,000,000 tonne-kms. On the world scale, a total increase in all traffic of 12 percent on the year 1959 was recorded (in terms of tonne-kms).

A Narrow Margin of Profit

The airlines' financial results, namely operating revenues of $5,505,000,000 against expenses of $5,448,000,000 or, in other words, an operating margin of $57,000,000 (one percent of turnover) before taxes, interest, dividends and other charges, are commented on by Sir William P. Hildred as follows :

"This margin is just ridiculous to meet the demands of a growing industry or the pressures of rising costs. Financially, therefore, the situation of the industry is precarious and an affront to commonsense. It cannot be allowed to drag on year after year at this figure."

The Diagnosis

Sir William attributes the airlines' disturbing financial results to the fact that, despite the decline in numbers of aircraft, capacity is increasing ; to the structural transformation of air transport ; to the difficulties in achieving further cuts in fares ; and above all to the irresponsible overburdening of the airlines with user charges, such as landing fees and air traffic control contributions.

Matériel

At the end of 1960, IATA members had a total of 3,376 aircraft comprising 382 jets, 480 turboprops, 2,447 piston-engined aircraft, and 37 helicopters. Disposal of surplus piston-engined aircraft is still a serious problem, although the IATA members had turned over a number of these aircraft to charter operation. For instance, between January and May, 1961, the number of charter passengers on the North Atlantic increased by 46 percent.

The world's airlines now have some 500 jet aircraft currently in service and, by the end of 1961, this number will be approximately 620—about two-thirds of the total so far ordered. Each jet starting service now has about twice the capacity of the piston-engined aircraft it replaces. It is, consequently, quite obvious that the load factor is constantly declining, despite the increase in passengers. In the first half of 1961, as compared with the same period in 1960, the number of scheduled passenger flights increased by 10.1 percent, but seating capacity expanded by 47.2 percent and load factors dropped by 15.5 percent despite a 12.3 percent increase in traffic. This applies to the North Atlantic, but the same phenomena were evident on other routes. " We intend to grow up into our capacity, like the growing boy who is sent to school with a jacket that is still three sizes too large for him. I have little doubt that traffic, like the boy, will be bursting the seams of this particular jacket long before it wears out," as Sir William put it.

The Market's New Look

Sir William stated that air transport still remains essentially a public service, but that it already depends, not on people who *must go* somewhere, but on those who must be *persuaded to go*. As a consumer industry, it is sensitive to economic and political changes, and must moreover compete for consumer income with many other suppliers of necessities and luxuries. In other words, the airline industry must be as resourceful as the manufacturers of sporting goods, television, washing machines, and automobiles—in attracting consumer income. Since the end of the Second World War, a new generation has grown up, which has led to a radical change in the habits and tastes of the airlines' customers.

User Charges

Sir William is convinced that landing fees, as well as charges for using airport and air navigation facilities have risen alarmingly in recent years. In 1959 alone, scheduled airlines had to pay out $112 million in landing fees (total operating margin in 1960 was only $105 million, and in 1960 down to $50 million). Whilst, over the last three years, general operating costs have increased by a third, landing fees alone have gone up by a half. Although it is more difficult to unravel the cost of using air navigation facilities, Sir William has reason to believe that these are increasingly even more rapidly than landing fees.

Since the beginning of 1960, landing fees have been increased by between 10 and 100 percent in the United Kingdom, Australia, Switzerland, Cairo, Malta, Amsterdam, Tel Aviv, Montreal, Warsaw, Dharan, Tokyo, Bangkok and Hong Kong. The most damaging increase of 33$^1/_3$ percent was imposed by the British Ministry of Aviation as from April 1st, 1961, which followed increases of 28 percent in 1959 and of 50 percent in 1957. More than 40 IATA members, some with a very high frequency of services into London Airport, have been affected by these increases. Another particularly detrimental levy was the $64 per flight charge imposed by Canada as from January 1st, 1960, for navigation facilities provided in the North Atlantic area, which is also levied on aircraft which overfly Canada without landing.

Sir William had complete understanding for the budgetary worries of the various governments concerned, but stressed that they should realise that their exchequers profit in no small way from increases in tourist traffic, thanks to air travel. Against the airlines' narrow margin of $50 million in 1960, the $132 million for charges is a very big item. But when compared with the more than $7,000,000,000 accruing to the economies of the countries receiving tourists, it is a paltry sum.

In short, the IATA members must make these points clear to their respective Governments :

— that governments bear an inherent responsibility for safety in the air ;
— that this responsibility is exercised not only on behalf of airlines, but on behalf of all air users and third parties on the ground ;
— that the whole community benefit from the services which airports and navigation facilities make possible ;
— that airlines should bear a fair share, but not the whole burden, of these ground facilities.
— that checks, in the form of increasing user charges, on the policy of decreasing the lowest air fare will harm the tourist industries and governments of the countries concerned even more than the airlines ;
— that governments should be prepared to bear a just proportion of the burden themselves.

*

We must unfortunately forgo the last sub-heading to this article, as the Director General of IATA said very little about one subject which we would have gladly heard more of. We refer, of course, to a reduction in fares.

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* ICAO definition, i.e. scheduled airlines of all countries save the USSR, the People's Republic of China, and other non-contracting states.

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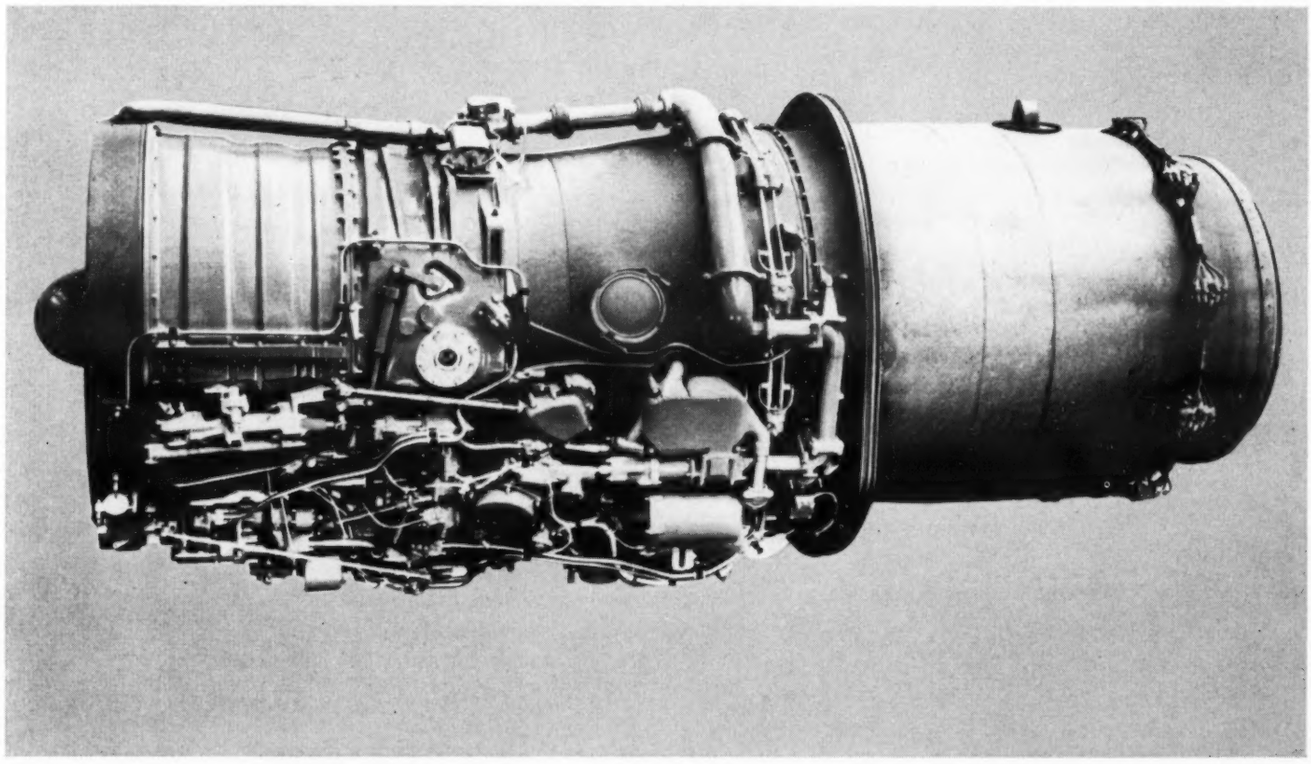

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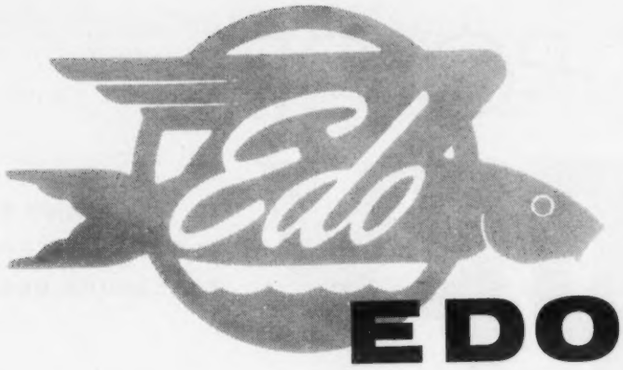

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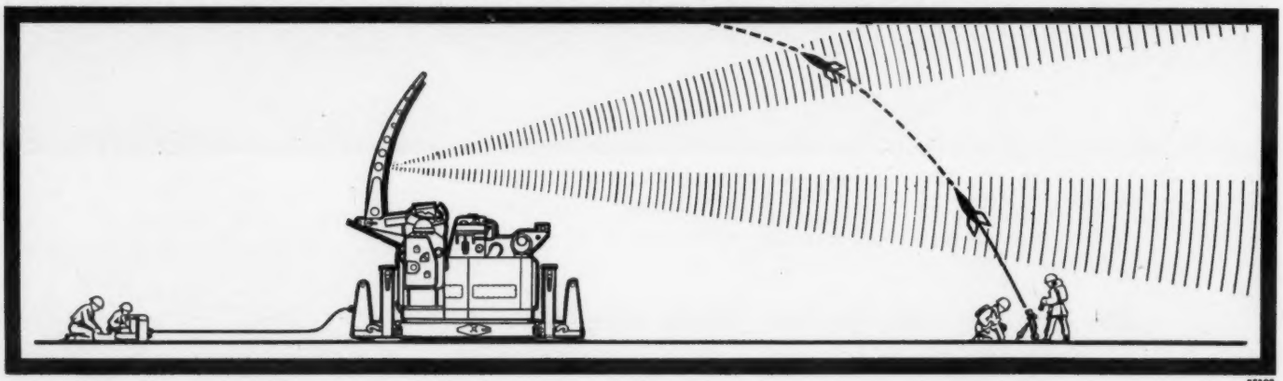

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But now the other eye has been opened. Hughes' new 3-dimensional—or stereoscopic—radar presents a scaled-down "cylinder of sky." Watching this radar, you could see the earth, the air space above and aircraft represented with a definition never before possible. The result: planes could move through busy intersections with new speed and safety.

This new radar display console—called Stereoscan—has two Hughes Tonotron picture tubes which are combined to make this startling 3-dimensional view possible. Because they remember images—they produce a radar picture where the "blips" leave contrails like a jet. It is these patterns that clearly show the direction *and* altitude *and* distance which separates the planes.

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Hughes 3-D radar display console can give a continuous view of sky activity. Integrated with a complete control system, it would tell air traffic controllers if planes were on a collision course. They could make swift decisions and direct air traffic in a fraction of the time it takes today.

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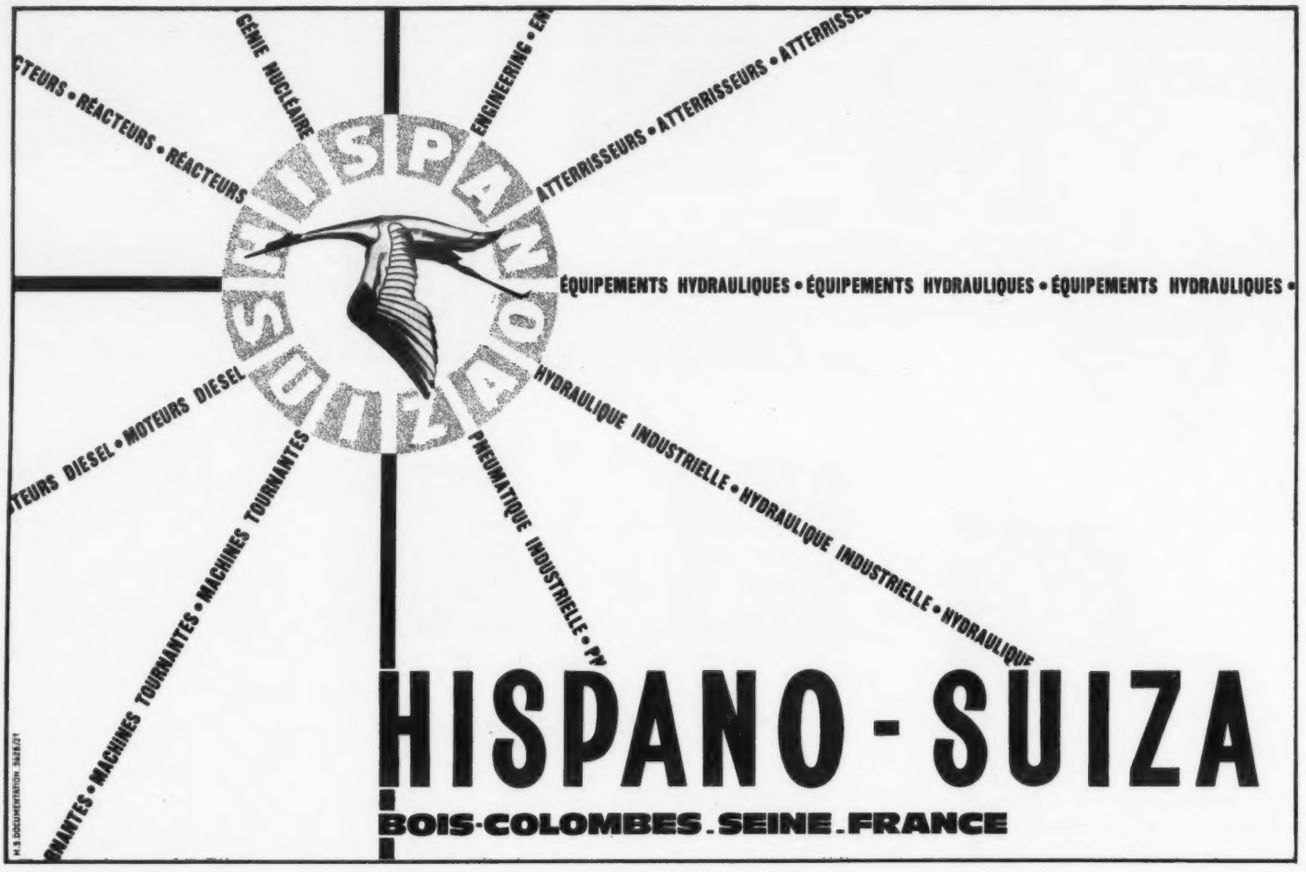
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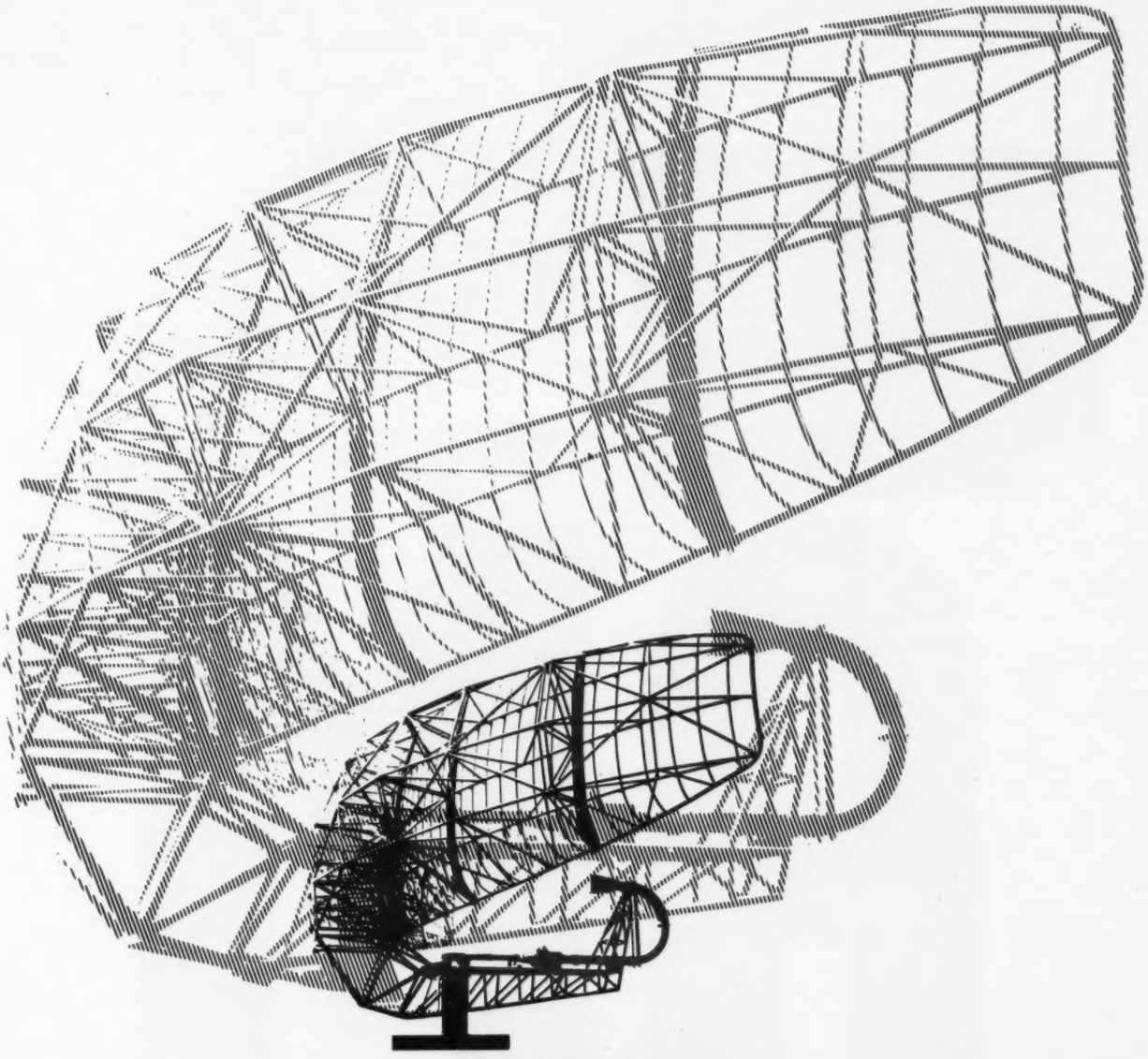

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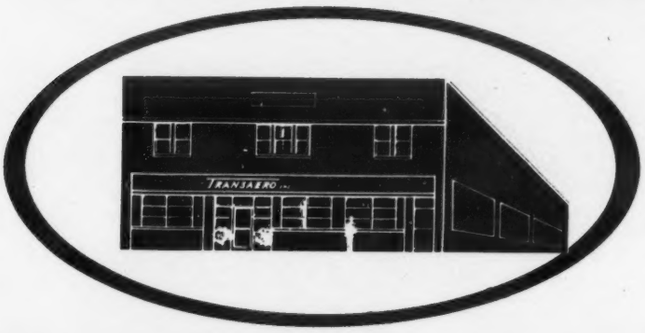

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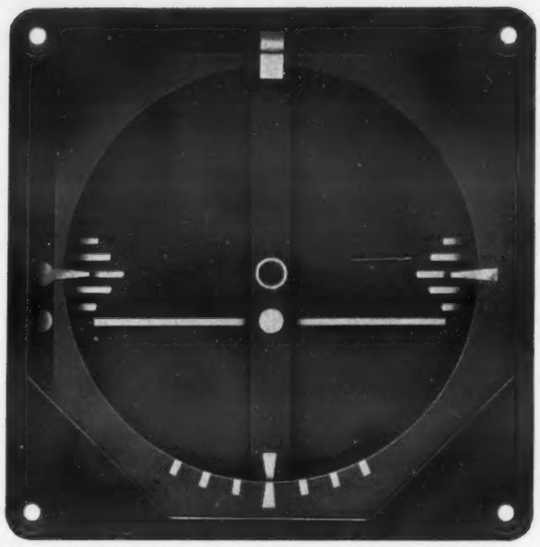

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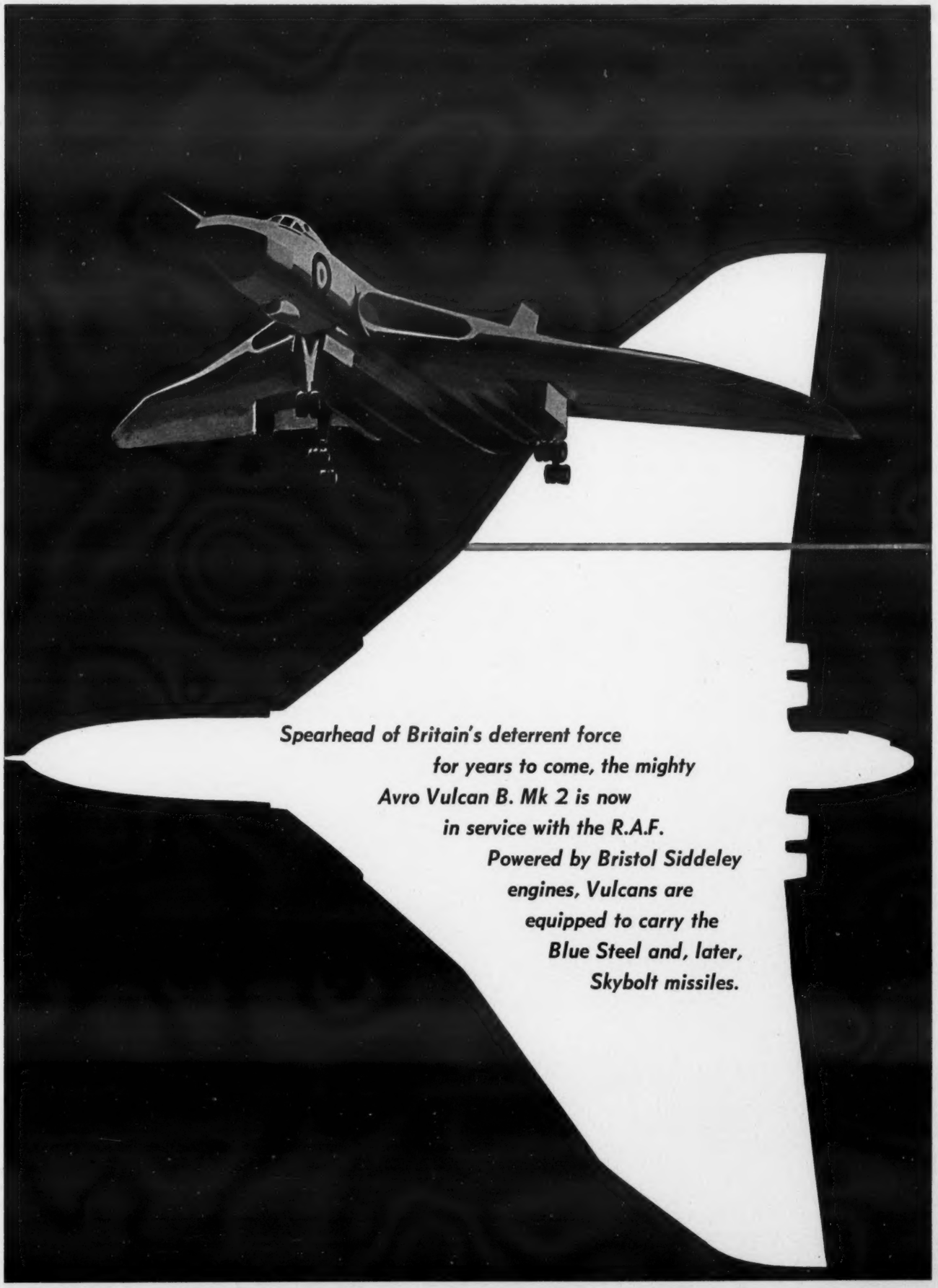

Spearhead of Britain's deterrent force for years to come, the mighty Avro Vulcan B. Mk 2 is now in service with the R.A.F. Powered by Bristol Siddeley engines, Vulcans are equipped to carry the Blue Steel and, later, Skybolt missiles.

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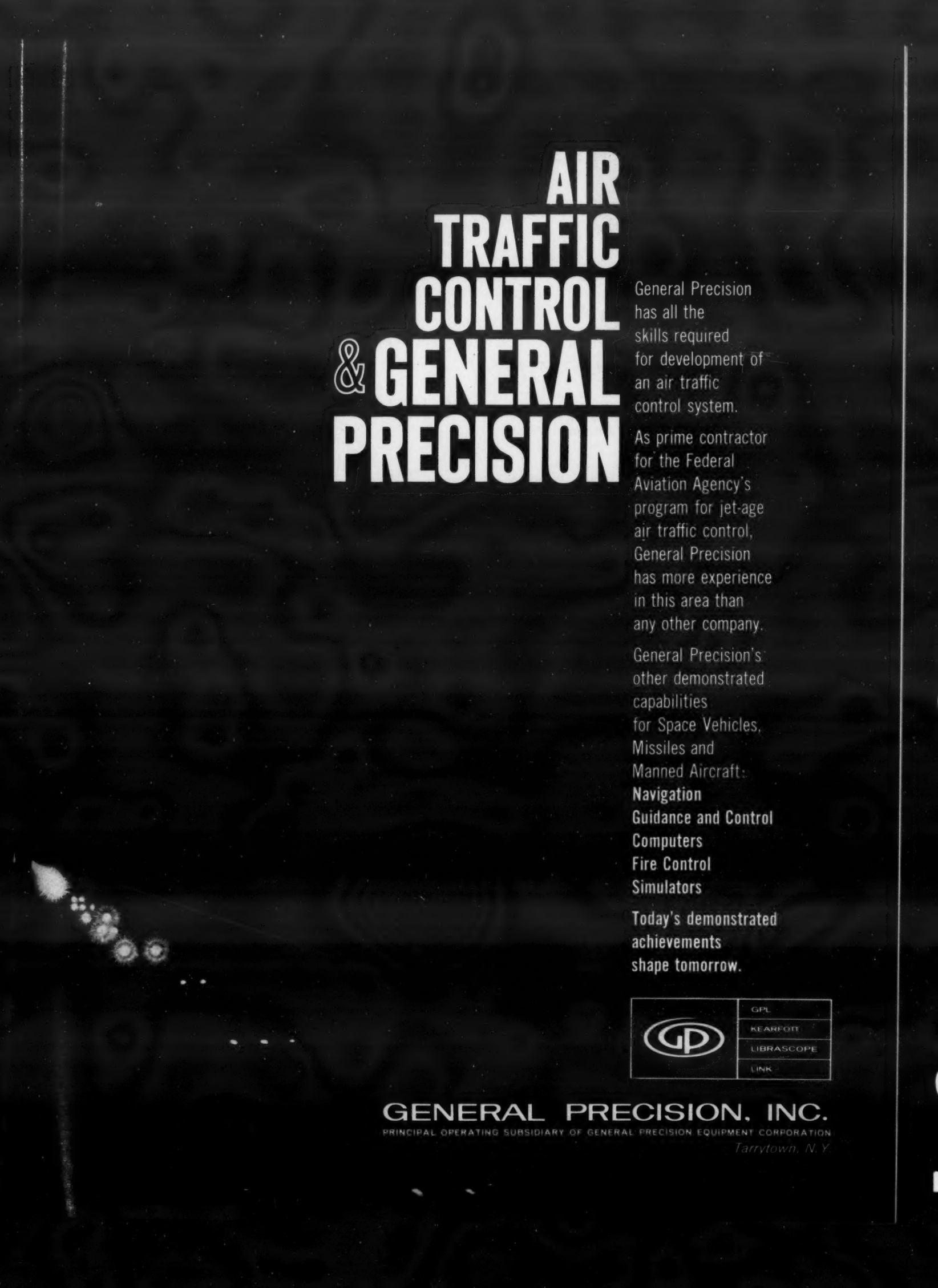
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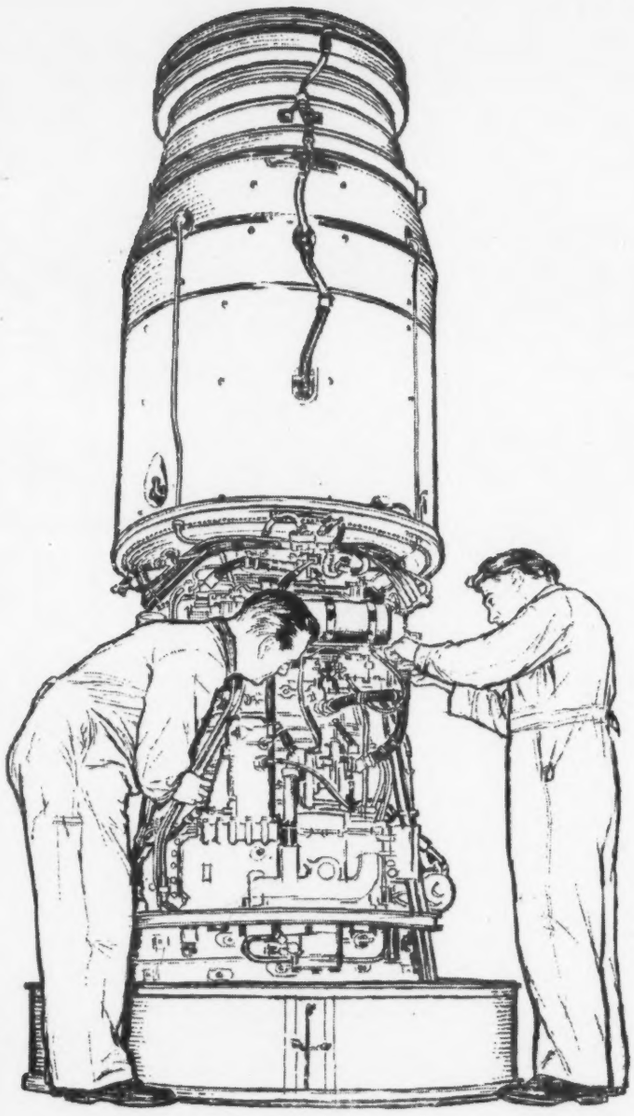
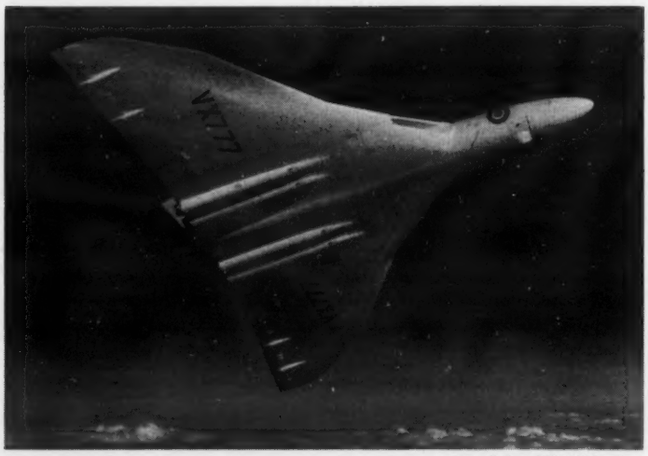
Olympus—for supersonic economy at Mach 2 plus



An advanced version of the Bristol Siddeley Olympus is now under intensive development for British Aircraft Corporation's TSR 2. It will give this unique tactical support reconnaissance aircraft an exceptional performance at speeds up to Mach 2 and over.

THE RIGHT QUALITIES...

The Olympus has the ideal thermodynamic cycle for the economic propulsion of a supersonic aircraft at Mach 2 plus and embodies all the qualities essential for such an application: high power at high altitude; extremely low fuel consumption; great operational flexibility; a long overhaul life; a very high thrust/weight ratio; and excellent handling qualities.



Avro Vulcan Mk 2 V-bomber

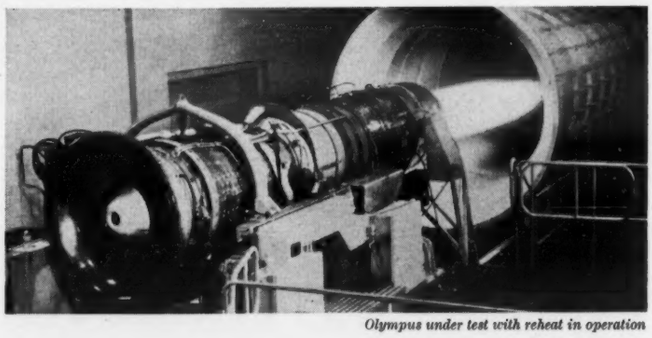
...PROVED IN SERVICE

The Olympus has proved itself in several years' service, as the powerplant of the Avro Vulcan V-bomber to be one of the most successful turbojets ever built. Maintenance is exceptionally low—last year, for example, on a 26,000 mile round-the-world tour, the maintenance required was negligible.

The truly astonishing built-in potential of the Olympus has been confirmed by the threefold increase in power from the 11,000-lb thrust dry of the original production engine, to the 33,000-lb thrust with reheat of the latest version.

SUITABILITY FOR SUPERSONIC AIRLINERS

Already selected for the RAF's most up to date supersonic aircraft, the Olympus will clearly require relatively minor changes to adapt it to the requirements of a supersonic airliner in the same speed category.



Olympus under test with reheat in operation

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The Four Cardinal Points

As the year draws to its close, four major questions confront the world of aviation. One is peculiar to the USA, whilst the other three affect all the aeronautical great powers.

*

The Berlin crisis reversed the trend in the field of armaments. In the USA, in particular, the happenings resemble those seen at the beginning of the Korean war, and America is now to spend some 60,000 million dollars on its own defence and that of the Free World. This is a handsome sum. Granted, it includes the credits allocated to tne armed forces, industry, the atom and space – in other words, everything which constitutes defence or contributes to it. But the accent is on the atom. The USA's atomic weapon stocks, now equivalent to 35,000 megatons of TNT, are to be boosted up still further, and besides this, many new means of transport and launching are to be provided. In accordance with the directives on defence issued by President Kennedy in his now famous message of March 29th last, Defense Secretary Robert S. McNamara wishes to expand the *Minuteman* and *Polaris* missile programmes substantially, raising *Minuteman* production to 900 and increasing the number of *Polaris* submarines planned from 29 to 41. This would still be far short of the fulfilment of the USAF and US Navy demands for a total of 3,900 ballistic missiles, but the proposed expansion, if accepted, would add 500 to the arsenal of 132 *Atlas*, 108 *Titan*, 600 *Minuteman* and 464 *Polaris* intercontinental rockets at present under construction.

Those responsible for America's defences have drawn the logical conclusion from the Red Air Force's 1961 display at Tushino and the anti-aircraft defences are being reinforced not only by air-to-ground missile batteries but also by supplementary squadrons of Convair F-106 fighters. Lastly, the celebrated "return to conventional forces" coupled with the drive towards flexibility has led Mr. McNamara to provide for the manufacture of some 300 Douglas A4D5 *Skyhawk* naval combat aircraft as reinforcement for the American tactical forces.

This new programme, taken together with the space effort, lays more stress than ever before on deterrence based on missiles and thermonuclear explosives. The considerable endeavours to be made in this direction will extend over several years, and will help to re-shape the American armaments industry. As far as space is concerned, it is of more the problem of improving the means of propulsion which is pre-occupying the USA; it is recollected with some bitterness that Alan Shepard was launched into space by a *Redstone* with a thrust of some 70,000 lb, whereas Gagarin's capsule was put into orbit by a multi-stage rocket with a total thrust estimated at about ten times this figure.

*

The second major problem facing the world of aviation is the supersonic commercial airliner. By authorizing the first 12 million dollars to enable a start to be made on the project of an airliner to fly at Mach 3—3.5, the American Senate has given implied approval to a 600—700 million dollar research and development project. The flights already carried out by the X-15 and those to be made by the B-70 experimental aircraft will doubtless contribute to the solution of the technical problems associated with the aerodynamic formula for this supersonic aircraft of canard design, namely those of construction in steel; of transparent window materials suitable for the very high friction temperatures encountered at these speeds; of special fuels; of engines with compression ratio low enough for good cruise performance yet high enough to keep specific fuel consumption at a reasonable level; and of keeping noise within tolerable limits.

Across the Atlantic, an important factor in promoting acceptance of the Mach 3, as opposed to the Mach 2, answer was that the airframe designers will in this way be obliged to bridge the technical gap between the construction materials suitable for Mach 2 and those required for flight at Mach 3 upwards. This is a process which will take time, and thus allow unrushed preparation for the future and amortization of the expensive jet fleets which have only recently gone into service. Mr. William Littlewood, Vice-president of American Airlines, recently said that even such a powerful concern as North American would not be in a position to have fruitful discussions about the Mach 3 airliner prior to 1964.

Coming back to this side of the Atlantic, those concerned in both Great Britain and France appear to have opted for the Mach 2.2 and this because, to mention only the opinions recently voiced by BOAC, Bristol, and Sud-Aviation, "it really can be achieved." There are, nevertheless, some differences of opinion concerning the dimensions of such an airliner and its average length of haul; the British lean towards the long-haul airliner, whereas the French, in the wake of the highly successful *Caravelle*, prefer a medium-haul aircraft. In this picture, the French project should be seen rather as complementing the American programme, with which the British are in competition, at any rate as far as range is concerned. For this reason, M. Georges Héreil championed American-European cooperation during the last Albert Plessman Conference at Delft and proposed that, in view of the financial and technical effort involved in projects of this kind, the American, British, and French Governments should undertake only such programmes as are complementary, and that the interested countries in Western Europe should pool resources to complete at least one such programme.

However that may be, this is one field which is being organised and for which funds to cover preliminary research and other work will certainly be forthcoming in 1962. The aircraft industry will find in this some measure of compensation for the slow but steady reduction in orders for military aircraft. If Great Britain joins the European Common Market, this will no doubt smooth the way for a common project in which the great names in European aviation would join forces. The United Kingdom is already offering the appropriate powerplants to most European design offices in order to secure a substantial share of the work involved in such a project.

*

The third cardinal point is of a scientific and technical nature. It lies in the efforts being made on all sides in two directions. On the one hand, it is sought to develop a strike aircraft capable of operating close to ground level at supersonic speeds and, on the other, to increase lift and, at the same time, achieve high maximum speeds. An American journal announced a few weeks ago that the British TSR.2 would be supersonic, and Republic likewise announced that its future combat machines would have the same quality. The USAF's specification for a new heavy tactical aircraft could hardly be met without recourse to "variable geometry," whilst the characteristics demanded of STOL aircraft involve a considerable increase in lift, which the designers hope to achieve by boundary layer control, a method pioneered by Lockheed with the *Hercules BLC*. This is a field in which swivelling wings and swivelling engines open up entirely new possibilities to all branches of the aviation technology.

*

The fourth feature of the aviation picture at the turn of the year is the NATO demands for the development of a strike and a transport aircraft. There is hardly a company in the business which is not endeavouring either to offer a direct answer to these NATO requirements or to participate at a later date when the aircraft in question go into production. In the sphere of interallied cooperation these projects mark the beginning of a new and happy phase. On this occasion, NATO is at last proposing to standardise the main aircraft required for common defence by selecting the best prototype and then building the aircraft as a joint venture. If these projects come to fruition, and thus serve to complement the bilateral and multi-lateral joint production agreements, aeronautical research and construction in Western Europe will cease to be strictly national, and become European, if not "North Atlantic," matters. To reach that point will take years of patient effort and many impossibilities will have to be admitted. As far as the two most recent NATO projects are concerned, a division of responsibility is beginning to emerge, with Great Britain monopolizing the powerplant, Continental constructors offering their airframes, and manufacturers of electronic equipment from across the Atlantic straining every nerve to be represented in the competition.

1962 should see the start of the research and, in part, of the development involved. There is thus no shortage of work, which will be along new, rational, and, without doubt fruitful lines. ←

The Future of the Heavy Turbine Helicopter

To begin with, the title or, to be more precise, the word "heavy" requires definition. At what all-up weight does a helicopter fall in the "heavy" class? Any limit chosen is more or less arbitrary but, unless we are mistaken, it has recently become the established practice to classify helicopters with a take-off weight of over 11,000 lb as heavyweights. To facilitate comparison of the principal data relative to helicopters in the various classes, our table (see page 1508) also covers medium turbine helicopters.

As the title further indicates, this article is confined to turbine helicopters. It could be foreseen years ago that the gas turbine would make the same triumphal progress as powerplant for the helicopter as in the case of fixed wing aircraft, for its advantages were obvious:

- low weight (reduction of engine weight by two thirds and more as compared with the piston engine) and small space requirement;
- no need for cooling fan and clutch (free power turbine);
- longer life;
- substantially less vibration, resulting in greater comfort for the occupants;
- no warming-up time (of particular importance in tactical operations);
- if installed horizontally, the turbine delivers a worthwhile residual thrust.

In addition to this, military planners are interested in simplifying logistical problems by reducing their fuel supply requirements to a single type. As far as operating costs are concerned, the high fuel consumption is largely offset by the lower price of kerosene (or JP-4 etc.), and the main disadvantage lies in the restricted range. Since the helicopter, given its limited cruise speed, is in any case not an advantageous vehicle for long range operations, this disadvantage is not a decisive factor. Exceptions to this are submarine reconnaissance and ASW missions, in which the helicopter can be used efficiently and is a reasonable proposition only if it has an effective duration (in terms of both time and distance) of several hours from its floating or static base.

The technical breakthrough

Some years ago, when the first serious VTOL and STOL projects began to emerge in their many different configurations, there was no lack of doleful voices prophesying a thin time for the helicopter. Many constructors did indeed suffer disappointments and reverses, although this in no sense amounted to a general crisis. Now, on the strength of the procurement programmes which have so far been announced, the industry, considered as a whole, should have sufficient employment for the immediate future. The US Army is considering placing orders for no less than 4,000 light observation helicopters, a contract for which Bell, Hiller und Hughes are competing. To put this figure in perspective, Sikorsky's total production of helicopters since the firm was established up to the end of last year was 3,536. In Europe, too, there are well-founded hopes that the French and German Defence Ministers' agreement to cooperate in the further development of the Sud-Aviation *Frelon* SA.3200 will, in the end, lead to a European production programme for a NATO multi-purpose helicopter; well informed circles put the requirement for such a helicopter at about 1,000 machines. If the helicopter agreed upon is the *Super Frelon*, the purchase price can be expected to be about NF 3.5 million per helicopter — in other words, a programme approaching the $ 1,000 million mark.

What is behind this sudden boom in helicopters? Is it current military thinking, which wants to meet the threat of surprise nuclear attack by a policy of "mobility at any price"? This is only part of the story. The main reason for the success of the helicopter lies in the intensive efforts of the constructors, who have spared no pains to bring the helicopter through its teething troubles, as the following review shows.

– Today, highly efficient stabilization systems help to take the strain off the pilot; these allow protracted operations and are indispensable for all-weather capability. In conjunction with automatic control equipment they ensure that the helicopter will accomplish its missions in the optimum manner. The Sikorsky HSS-2, for instance, which has been developed as a submarine hunter and killer, can make a completely automatic transition from forward to hover flight, in order to submerge its sonar equipment. An autopilot, which receives impulses from various sources, including a Doppler radar and a radio altimeter, maintains altitude, attitude, and position in hover.

– Airborne navigation and landing aids now give the helicopter pilot the ability to find his way by night and in poor weather conditions. Although the instruments concerned are, basically, not novel, it was essential to adapt them to the flight conditions of the helicopter, namely low speeds down to nil, low cruising altitudes, and vertical take-off and landing. All-weather capability makes anti-icing or deicing systems for rotor blades, engine intakes, and windscreens imperative.

– Careful aerodynamic configuration of the fuselage (retractable undercarriage, for example), the use of thinner but broader rotor blades (mainly problems of production and strength of materials), an increase in the number of blades, reduction of rotor load in forward flight by the use of stub wings, the fairing of the rotor head, and other similar measures, should enable cruising speeds in the neighbourhood of 220 m.p.h. to be attained.

On behalf of the US Army Transportation Research Command, Sikorsky has been working on the design of a helicopter for carrying a payload of 4,000 lb at a speed of 200 m.p.h. over a distance of 150 miles. Maximum speed has been laid down as 224 m.p.h. and ferrying range (without payload) as 2,400 miles. Essentially, the design is based on the HSS-2, and it will use the same engines (two General Electric T58 turboshaft engines) as well as a similar five-blade rotor. Careful configuration of the fuselage, which is provided with a fully retractable undercarriage, minimises drag in cruise flight. The tail of the helicopter is similar to that of a fixed wing aircraft, namely large horizontal stabilizers with control surfaces and a conventional rudder assembly (see picture on page 1506).

The Vertol Division of Boeing has also announced plans for continuing the development of its 107 type in the sense of higher speed and all-up weight, namely the Vertol 107-VI with faired rotor hubs, thinner blades, and retractable undercarriage; powerplant is two General Electric T58 turboshaft engines each 1,400 shp, max. take-off weight 19,130 lb, and cruise speed 176 knots, as against the Vertol 107-II's 133 knots. And a projected version of the Army's Vertol YHC-1B *Chinook* helicopter would have a speed of nearly 230

This shot of the Westland *Belvedere* tandem helicopter shows the layout of the landing gear and the form of the stabilizing fins. The *Belvedere* is powered by two Napier *Gazelle* turboshaft engines, each of 1,650 s.h.p., and can carry up to 19 fully-equipped troops or external loads of 6,000 lb.

The prototype of the Boeing Vertol 107-II landing at the Wall Street Heliport in the centre of New York. Powered by two General Electric T58 turboshaft engines, this helicopter can carry 25 passengers at a speed of 150 m.p.h. Thanks to the interchangeable luggage containers in the rear of the fuselage, turn-round times are reduced to the minimum. Automatic stabilization, together with a Lear L-5H automatic pilot, provides the Vertol 107-II with all-weather capability. New York Airways will put this model into service in January, 1962.

knots, thanks to load on the two rotors being reduced by two pairs of stub wings.

The Derschmidt rotor should also be mentioned. The inventor calculates that it will make possible helicopter speeds of over 300 m.p.h. The idea is to modify the rotation of the blades by the insertion of mid-span hinges and thus extend current aerodynamic limits (sonic tip speed of the advancing blade and flow breakdown on the retreating blade). It remains to be seen to what extent the considerable mechanical difficulties of this concept can be overcome; trials have for some time been in progress at Bölkow-Entwicklungen KG.

– Thanks to progress in the field of rotor aerodynamics, it has become possible, with the extensive aid of electronic computers, to make accurate preductions of flight characteristics and performance while at the design stage. This is particularly true of the oscillation behaviour of the rotor blades, which is of great importance both from the point of view of flight mechanism and as regards strength.

– Consistent simplification of design, reduction in number of components and standardization of frequently recurring parts (such as screws, bolts, and locking devices) have, in the case of some modern helicopters, significantly cut production costs.

– Increasing and standardizing the life of wearing parts helps considerably in keeping maintenance costs down.

– Installed maintenance platforms and easy access to all moving parts make the helicopter largely independent of fixed ground systems, a vital consideration for operations in the combat zone. If maintenance and minor repairs can be carried out with the aid of the helicopter's own resources, periods of mobility for longer periods are possible. The Vertol 107-II (see *Interavia* 2/1961, page 204) may be taken as a typical example of a design which is governed mainly by the demand for versatility and for utmost simplicity of maintenance.

One can sum up by saying that most of this progress redounds to the benefit of the heavier weight helicopter, since many constructive refinements can be carried out only on helicopters of some size, and the expense of an automatic stabilization and navigation system is not justified on smaller helicopters.

One Rotor or Two?

Of the numerous possible arrangements of the main rotors, three have prevailed. These are: the single rotor; two rotors in tandem; and overlapping synchronized rotors or two coaxial rotors arranged one above the other. Heavy helicopters fall into one or another of the first two categories, the majority of the manufacturers — including Sikorsky, Sud-Aviation and the Soviet designers—having adopted the single-rotor design, whereas Vertol, the Bristol Division of Westland, and Jakovlev favour the tandem. Both systems have advantages and disadvantages. The supporters of the single rotor advance the following arguments in its favour:

- Relatively low production and maintenance costs as compared with multirotor helicopters, there being only one rotor head with all its power transmission and control components.
- The length of the fuselage imposes no limits on the diameter of the rotor, which is not true of the tandem helicopter.
- Owing to aerodynamic interference, the rear rotor must be placed high, which spells extra weight and greater overall height, such as to rule out accommodating the vehicle in the hangar decks of carrier vessels.
- The heavy and expensive synchronization gearing between the main rotors is eliminated.
- The tandem helicopter also requires an automatic pitch control coupling device on the rotor for autorotation flight.
- The single rotor helicopter is more stable than the tandem when flying at low altitude (within the ground effect).

The arguments of the protagonists of the tandem helicopter, on the other hand, run like this:

- The so-called single-rotor helicopter is, in fact, a twin-rotor helicopter, since the tail rotor must be synchronized with the main rotor, to compensate the torque.
- The dynamic instability of the tandem helicopter in hover flight and at low speeds is much less than that of the single-rotor type.
- The widely separated rotors increase the permissible movement of the centre of gravity,

The Westland *Rotodyne* is a combined fixed-wing aircraft and helicopter. Fitted at present with two Napier *Eland* turboprops each of 3,000 e.h.p., the later production model is to have two more powerful Rolls-Royce *Tyne* engines and will carry up to 65 passengers as a civil transport or 73 fully-equipped soldiers in the military version. The rudder assembly is of particular interest as the three upper fins can be folded sideways to prevent damage to the flexible rotor blades during landing and on the ground.

▲ Prototype of the Vertol YHC-1B *Chinook* military transport helicopter, 28 of which have been ordered to date by the US. Army. Powered by two Lycoming T55-L-S turboshaft engines each of 2,200 s.h.p. the *Chinook* can carry a payload up to 17,600 lb. Service tests are to start next Spring.

◀ The Kaman KU2K-1 *Seasprite* is characterised by its retractable landing gear and General Electric T58-GE-6 1,100 s.h.p. engine mounted above the fuselage. It is already in production for the US Navy and a civilian version to seat 13 passengers is also planned.

◀ This projected transport helicopter by Sikorsky could attain a maximum speed of 224 m.p.h. This aircraft is a development of the HSS-2, and the first design objective was a minimum of drag; it has retractable landing gear and a faired rotor head. The tail of the fuselage is similar to a conventional aeroplane tail unit.

A mock-up of the Sud-Aviation SA.3210 *Super Frelon* amphibious helicopter. Two prototypes of this aircraft, powered by three Turboméca *Turmo III3* turboshaft engines, are under construction. Weser Flugzeugbau and Sikorsky Aircraft are also concerned in the development programme which, if directed towards NATO requirements, could lead to a European helicopter programme.

thus giving the user greater freedom in the distribution of payload.

• The tail rotor of the single-rotor helicopter requires seven to ten percent of the total output of the powerplant. The single-rotor helicopter is moreover more difficult to fly since, on acceleration, rotor torque increases, necessitating a simultaneous increase in the pitch of the tail rotor blades.

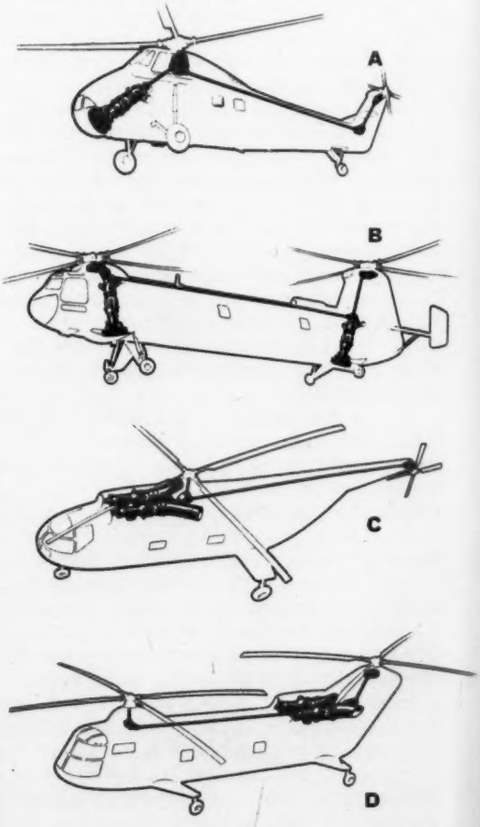
• Basically, the tandem helicopter does not require a cyclic variation of the blade pitch as the tilting moment is achieved by differential and simultaneous adjustment of the pitch, of the two rotors.

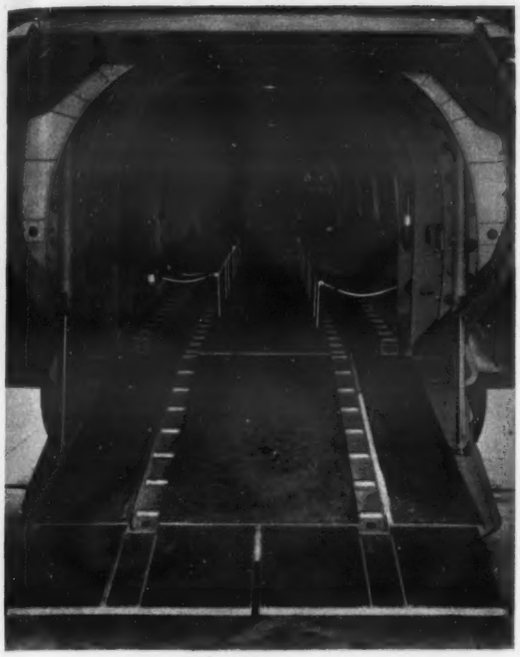
The products of both schools of thought have been well tried, and have reached a similar degree of operational maturity. It is therefore the dominating design requirements in each case which will be decisive.

Helicopter or S/VTOL Aircraft?

Missions in which it is a question not only of vertical take-off and landing but also of longish hoverflight will probably always continue as the preserve of the helicopter. Forgetting the heavy fuel consumption of a VTOL aircraft in hover flight, one cannot for instance imagine how an aircraft of this type could work as a "flying crane." Even for

Four typical examples of the installation of turboengines in heavy helicopters. Two helicopters actually in service, fitted with *Gazelle* engines (the Wessex "A" and the Belvedere "B") and two helicopters still under development ("C" and "D") have been selected for inclusion in this diagrammatic drawing provided by Napier. As these four specimens show, the angle at which the engines are installed, the position of the drive shaft to the rotor head, the arrangement of the reduction gearing, the transmission shaft layout, and the position of air intake and exhaust nozzles are all largely determined by the configuration of the helicopter itself.





The Vertol division of the Boeing Company has developed a built-in loading system for the military version of the Vertol 107-II. The system comprises a ramp which can be lowered downwards, guide rails for wheeled vehicles, and a hydraulic winch. The latter hauls the cargo aboard, and the slant of the fuselage (slope 4.5 degrees towards the rear) is used to advantage during unloading. By means of this installation, the crew can load or unload two tons within three minutes without assistence.

◀

▶

Sikorsky's most recent civil model is the S-61L, the propulsion system of which has been taken over from the HSS-2. Powered by two General Electric CT58 turboshaft engines each of 1,250 s.h.p., the S-61L carries from 25-28 passengers, according to cabin arrangement. It is shortly to go into regular passenger service with Los Angeles Airways and Chicago Helicopter Airways. If desired, the S-61L can be equipped with a special watertight fuselage, enabling the aircraft to float. Note the quick-change luggage "drawer" which originates from a suggestion by Clarence Belinn, President of Los Angeles Airways.

transport duties in the battle zone, later VTOL models should hardly displace the helicopter, but can rather be expected to complement it. Whilst the helicopter is lacking in range and speed, the fast fixed-wing VTOL aircraft will be lacking in versatility (e.g. it will not have amphibious characteristics) and probably in *absolute* independence of terrain.

To what extent the helicopter will compete with the light STOL turboprop transport only the future can say. In payload capacity they may be equal. Against the 125-190 m.p.h. advantage in speed on the side of the fixed-wing aircraft, which is however tied down to landing strips of a few hundred yards, can be set the extensive mobility of the helicopter.

It is just as difficult to gauge the prospects of these two competing types in the civil sector, especially where it is a question of short distance operation. The main factor here is profitability. Should the large helicopter or its relatives (combination-gyroplane etc.) not come up to expectation in respect of cost and noise, it appears quite possible that one day fixed-wing aircraft, capable of operation from short take-off/landing runways as well as with low operating costs, will step into the picture. Many traffic planners are convinced that, in any town with the necessary volume of traffic, a 200-300 yard landing strip can be built in a tolerably central position, for instance in the form of a floating platform on a river.

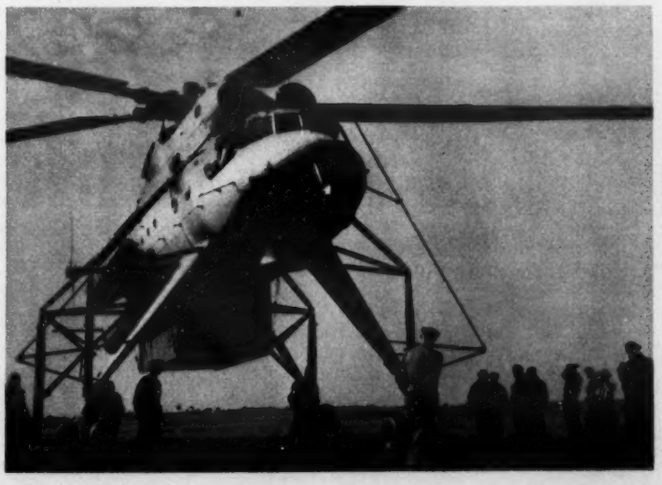
Operating Costs — a Handicap

In September 1959, the Deutsche Studiengemeinschaft Hubschrauber (German Helicopter Study Group), Stuttgart, published a research report concerning the commercial profitability of the helicopter, in which direct operating costs of 29 rotating-wing aircraft—including 4 hypothetical models—were compared with those of 25 fixed-wing aircraft. This very thorough study, based on copious documentation, confirms yet again that operating costs decline appreciably as size increases, but culminates in the sorry verdict that even large helicopters of 25-30 ton take-off weight would involve costs double those of comparable fixed-wing types.

In October, 1959, however, when the chief author of the report presented it to the WGL meeting at Hamburg, the representatives of two notable helicopter concerns—Friedrich V. Doblhoff (Vertol) and S. Sikorsky Jnr.,—cast doubts on the results of the investigation. Their grounds were that it was based on many old models and that, thanks to continuous technical progress (turbine powerplant etc.), more profitable types can now be offered. Despite all the optimism, it is impossible to overlook the fact that certain handicaps attach to the helicopter—as opposed to the fixed-wing aircraft—and that these are, so to speak, innate and irremovable. These are the 50 percent or so more power required per lb of all-up weight and the double to triple fuel consumption per flight mile. This means a steep reduction in payload capacity as route length increases.

The tenacity shown by Sabena, as well as some other feeder companies in the USA, in expanding their helicopter services is impressive. But this does not get over the fact that they are all working at a loss. Apart from the carriage of mail, Sabena's helicopters justify their employment only in bringing more passengers to the remunerative long-haul services.

The modern helicopters, specially conceived for passenger traffic, should represent a decisive step towards the helicopter which can be profitably operated in its own right. Increased safety in operation, thanks to several engines, coupled with all-weather and night flight instrumentation, can raise flying hours per year by leaps and bounds. Large doors, turbine propulsion, interchangeable baggage containers, and so on, reduce turn-round time to a minimum. Higher speed and greater seating capacity also favourably affect operating costs, since receipts are roughly proportional to the transport performance and costs to the period of operation.



The Soviet designer Mikhail L. Mil derived this "flying crane" from his large helicopter, the Mi-6. According to Tass, this helicopter set up a world record on September 23rd by transporting a payload of 16,000 kg (35,000 lb) to a height of 2,200 m (7,250 ft).

Table of Heavy and Medium Turbine Helicopters

Manufacturer Type	Powerplant Take-off rating (s.h.p.)	Main rotor diameter (ft) Number of Blades	Length of fuselage (ft) Overall height (ft)	Payload (lb) Take-off weight (lb)	Max. speed (kts) Cruise speed (kts)	Max. rate of climb (f.p.m.) Service ceiling (ft)	Hover ceiling (ft) With ground effect Without ground effect	Range (n.m.) Endurance (hrs)	Remarks
Heavy Class — Take-off Weight Exceeding 11,000 lb									
FRANCE									
Sud-Aviation SA.3210 Super Frelon	Turboméca Turmo IIIC, 3 × 1,320	62 4	55′ 10″ 16′ 3″	9,950[1] 25,355[1]	135 120	2,150 12,140	10,500 9,200	435[2] 3 +	In development; amphibious; ASW; Prototype: SE 3200 Frelon. [1] Max. [2] 30 min. reserve.
GREAT BRITAIN									
Westland Wessex I	Napier Gazelle (NGa.13), 1 × 1,650	56 4	38′ 6″[1] 14′ 3″	1,892[2] 12,600[2]	115 110	1,750 14,200	7,000 5,000	340 —	In production for Royal Navy; ASW; max. 12 passengers or 16 fully equipped troops; 2 crew. [1] With tail folded. [2] Civil version.
Westland Wessex II	De Havilland Gnome H.1200, 2 × 1,250	56 4	38′ 6″[1] 14′ 3″	2,517 13,500	120 115	1,540 20,000	14,200 10,000	300 —	Provisional data: max. 12 passengers/ 16 fully equipped troops; 2 crew; ASW. [1] With tail folded.
Westland Belvedere	Napier Gazelle NGa.2, 2 × 1,650	48′ 11″[1] 4 each	54′ 4″ 17′ 0″	6,000 19,000	120 120	1,000 17,300	8,500 6,000	65 —	In production; ASW; max. 19 fully equipped troops; 2 crew; tandem rotor; civil version in preparation. [1] Tandem rotor.
Westland Rotodyne	Rolls-Royce Tyne, 2 × 5,250	109 4	69′ 5″ 27′ 3″	18,350[2] 60,000	— 175–200	2,150[3] 10,000	— 9,000	575 —	2 × 3,000 e.h.p. Napier Eland; blade tip jets; passenger capacity 50–70. [1] Wing span 75 ft. [2] Payload plus fuel. [3] Vertical.
ITALY									
Agusta AZ 101G	De Havilland Gnome H.1000, 3 × 1,050	64 4	54′ 1″[1] 10′ 6″	11,440[2] 24,000[2]	143 125	1,280 16,000	9,850 —	245 —	Prototype under construction; ASW; 30–35 passengers. [1] Height of fuselage. [2] Useful load. [3] Max. 24,900 lb.
USA									
Sikorsky HSS-2	General Electric T58-8, 2 × 1,250	62 4	54′ 9″ 15′ 4″	6,446 17,300	130 120	1,780 —	8,200 —	500 —	Flight testing; US Navy amphibious helicopter; 4 crew; 25 fully equipped troops.
Sikorsky S-61L	General Electric CT58- 110, 2 × 1,250	62 4	54′ 9″ 15′ 4″	8,900[1] 18,700	128 118	1,600 9,500	7,000 5,000	270 —	In production; 25–28 passengers; civil version of the HSS-2. [1] Max.
Sikorsky S-64	Pratt & Whitney JFTD- 12A-1, 2 × 4,045[1])	72 6	87′ 5″[2] 24′ 4″	17,640 38,000	— 106	1,510 —	— —	184[3]	See Weser WF-S64 (Western Germany) below; crane helicopter; 3–5 crew. [1] De-rated, later version to have 4,600 s.h.p. [2] Including rotor. [3] 20 kts headwind.
Vertol/Boeing Model 107-II	General Electric T58-8, 2 × 1,250	50[1] 3 each	44 7[1] 16′ 10″	7,612 18,450	— 132	1,700 13,700	— —	215 —	Civil version of the Vertol YHC-1A; 25 passengers; in production; [1] Tandem rotor.
Vertol/Boeing YHC-1B Chinook	Lycoming T55-L-5, 2 × 1,940[1]	59 3	51′ 0″ 18′ 7″	6,600[2] 23,500	152 130	2,700 18,900	12,900 6,000	200 —	Military transport; flight resting; 33 fully equipped troops; [1] Improved version has 2,200 s.p.h. [2] Max. cargo about 17,600 lb.
USSR									
Mil Mi-6 (Hook)	Soloviev TB-2BM, 2 × 4,700	115 5	— —	26,500[1] 78,000	190 145	— —	— —	265 —	Recent version has stub wings to take load off rotor; up to 80 passengers; further development as crane helicopter. [1] Up to 7,900 ft; normal payload 16,600 lb.
WESTERN GERMANY									
Weser WF-S64	Pratt & Whitney JFTD- 12A-1,2 × 4,045[1] HP	72 6	87′ 5″ 24′ 4″	17,640 38,000	— 146	1,510 —	— —	54[3] —	Development in corporation with Sikorsky; crane helicopter; 3–5 crew. [1] De-rated, later version to have 4,600 s.h.p. [2] Including rotor. [3] 30 kts headwind.
Medium Class — Take-off Weight 4,500-11,000 lb									
FRANCE									
Sud-Aviation SE.3160 Alouette III	Turboméca Artouste IIIB, 1 × 870[1]	36′ 1″ 3	33′ 1″ 9′ 8″	2,290 4,630	115 105	900 13,100	6,560 1,800	315 3.6	multipurpose: 7 seats including crew; max. 8 fully equipped troops; in production; licence production agreement with Sweden. [1] Normal rating, here de-rated to 550 h.p.
GREAT BRITAIN									
Westland Gnome Whirlwind	De Havilland Gnome H.1000, 1 × 1,050	53 3	62′ 4″[1] 15′ 8″	1,230 8,000	95 90[2]	1,200 16,500	15,800 7,000	275 —	ASW; max. 10 seats; in production. [1] Including rotor. [2] Economic cruise 80 kts.
Westland Wasp	Blackburn A.129 Nimbus, 1 × 1,050	32′ 3″ 4	40′ 2″ 11′ 0″	1,950 5,300	120 115	1,490 20,000	17,800 —	280 —	Civil version of the Scout P.531-2; undergoing naval tests; in production. [1] Including rotor.
ITALY									
Agusta AB 204B	De Havilland Gnome H.1000, 1 × 1,050	44 2	38′ 5″ 12′ 4″	3,900[1] 8,000[2]	115 105	1,790 —	10,700 5,500	205 —	In production (Bell licence); 8–10 passengers. [1] Useful load. [2] Max. 8,500 lb.
USA									
Bell HU-1B Iroquois	Lycoming T53-L-5, 1 × 960	44 2	38′ 5″ 12′ 4″	— 8,600	110 95	2,000 —	15,400 —	250 —	8 passengers; 2 crew; latest model YHU-1D (Lycoming T53-1-9 — 1,100 s.h.p.) for 13 fully equipped troops plus pilot.
Bell Model 204B	Lycoming T53-L-9 1 × 1,100	94 2	38′ 5″ 12′ 5″	3,000[1] 6,500	125 110[2]	2,660 —	17,600 13,000	227 —	Civil version of the HU-1B Iroquois; in production; in licence construction at Agusta. [1] External load max. 4,000 lb. [2] At 6,000 ft.
Kaman H-43B Huskie	Lycoming T53-L-1B, 1 × 860	47[1] 2	25′ 0″ 15′ 6″	2,800 7,100	104 95	1,530[2] 25,000	21,800 18,000	205 —	Crash rescue; 1–2 crew; in production. [1] Two synchronized rotors. [2] Vertical.
Kaman HU2K-1 Seasprite	General Electric T58- GE-6, 1 × 1,050	44 4	52′ 2″[1] 12′ 5″	— 9,150	— —	— —	— —	— —	Reconnaissance; in production for US Navy; retractable undercarriage; 2 crew; max. 13 passengers. [1] Including rotor.
Sikorsky S-62	General Electric CT58-6 1 × 1,050	53 3	44′ 7″ 14′ 2″	2,960[1] 7,500	100 91	1,380 15,700	14,000 8,000	200 —	America's first turbine helicopter with FAA certification; 11 passengers; 2 crew; floatable; major components same as in the S-55. [1] Useful load.

Military Roles

The potentialities of helicopters in war had already been recognised before they were anywhere near operational readiness. Towards the end of World War II, Germany used some helicopters/gyroplanes for O.P. purposes. The development of heavy types for transport duties was also began at the time, but interrupted by the end of hostilities. The first attempts to call on the helicopter as an active weapon for offensive missions, were made some ten years ago in France, using the *Djinn* and *Alouette,* which were provided with wire-guided and unguided rockets and machine guns. The helicopter exploits the unevenness of the terrain in order to go stalking just above ground and, by making continuous use of natural cover such as wood and hills, can penetrate as far as the enemy lines. It is only actually to fire its weapons that the helicopter is obliged, for a short space of time, to leave its cover and elevate itself a few yards. Although these small helicopters proved their worth, in the Algerian war for example, it was left to the heavy types, such as the Sikorsky H-34 and the Vertol H-21, to play a decisive part in operations over a wider area.

In the American large-scale manoeuvre held in Louisiana in late 1955, heavy helicopters gave the following convincing proofs of their versatility.

– The classic reconnaissance by motorized cavalry was replaced by aerial reconnaissance undertaken by the army air corps, in which the helicopter unit "Skycav," in particular, proved its high value.

– Another unit had to undertake supply lifts and intervene directly in the fighting by dropping troops and arms in the battle area.

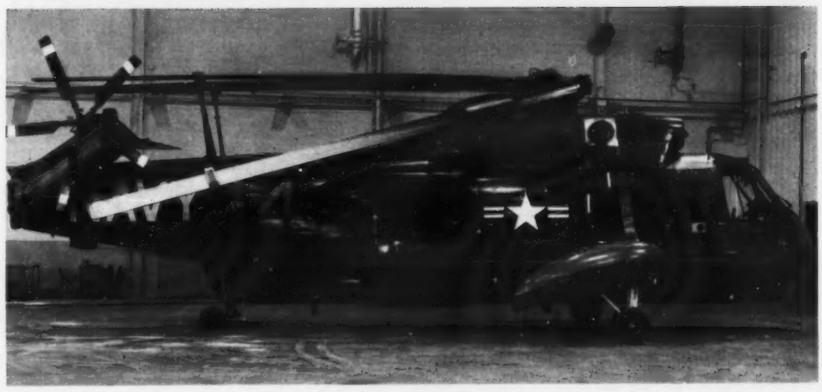
– Helicopters also served as flying command posts, thus carrying out a role which can be of capital importance in a nuclear war, as the helicopter can adapt itself with ease to the mobile scattered battle groups.

– Lastly it was the helicopters which, when all other means had failed, dragged out vehicles bogged down in the mud.

In the course of these manoeuvres no less than 530 tons of supplies and 5,000 soldiers were transported by helicopter.

In irregular warfare, the combat/transport helicopter has proved to be one of the most telling weapons. In Indochina, the French General Staff found to their cost that massed attacks against an extremely mobile enemy, operating in small groups, were completely ineffective. The only thing to do was to track the enemy units down to their hiding places, take up immediate pursuit and—since attack from the air was useless in the rugged country—bring up troops by air. The following tactics were found to pay dividends: a Vertol H-21, armed with a 20-mm gun, first engaged the enemy in order to scatter him; then, it concentrated its fire on one isolated group, continually circling round it; meanwhile, a second helicopter dropped troops in the vicinity; these troops then engaged the enemy on the ground, with effective air support.

On behalf of the US Army, General Electric has for some time been studying various armament for helicopters. As part of these trials, H-21s have been armed with non-guided 6.35-mm rockets and 12.7-mm machine guns, as well as SS.10, SS.11, *Entac,* and *Cobra* wire-guided anti-tank weapons.

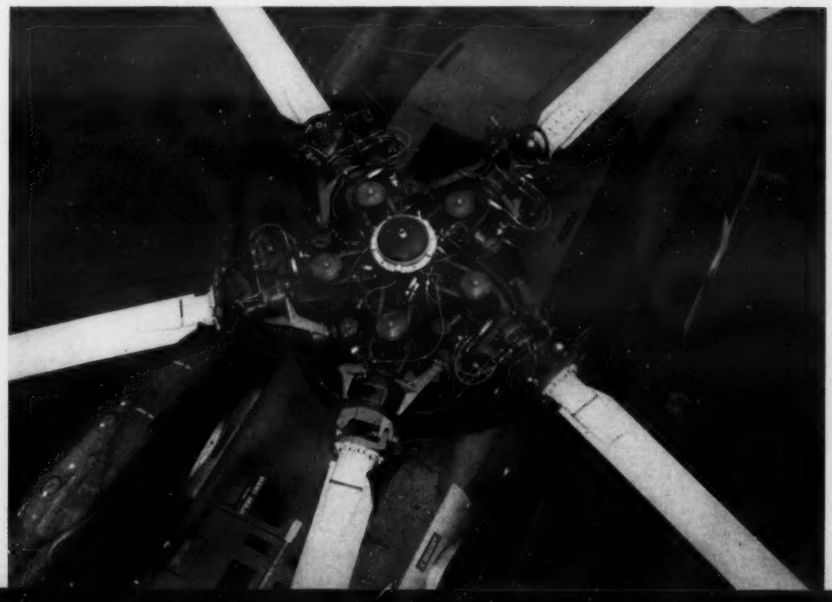


Top: the civilian version of the Sikorsky S-62. This model—the first American turbo-helicopter to be granted FAA certification—can carry up to 11 passengers for over 270 miles at a speed of 115 m.p.h. In the older S-62A, the rotor head and other main units of the S-55 are incorporated, whilst the S-62B has the S-58's rotor head. Both models are floatable and can consequently utilize practically any type of take-off and landing ground. On May 17th, 1961, the Sikorsky HSS-2 (below), developed for ASW purposes, set up a world speed record of 192.9 m.p.h. over a three-kilometer course. The HSS-2 is automatically stabilized and is capable of all-weather operation. The rotor blades can be folded under their own power at wind speeds not exceeding 45 knots.

There is, in any event, a double role for the helicopter in modern land warfare, namely *support of ground troops* and *transport of troops and supplies.* This twin function not only makes careful integration of the equipment essential but also demands an integrated overall design from the very beginning, one which takes into account all the operational conditions, yet is not too much of a compromise. Carefully devised loading systems—such as tail loading doors, an adjustable loading ramp, installed roller tracks, and built-in winches—are at least as important in the transport helicopter as in the cargo aircraft.

Whether or not the helicopter of today—in particular, the "heavyweight,"—is the last word in design is a question beyond the scope of this article. The helicopter has however now successfully made the critical breakthrough to become a stable and all-weather aircraft. And further progress is to be expected. One day, perhaps, it will be possible to bring down operating costs to a point where a wide civil market is thrown open to the heavy helicopter. ⟷

Details of the Sikorsky HSS-2's rotor head. The drag hinge, flapping hinge and the blade pitch-changing level can be recognized. The lowest blade is not foldable, but is positioned automatically over the fuselage before the other four blades are folded.



The Crane Helicopter

By Dipl. Ing. Cristoph Fischer, "Weser"-*Flugzeugbau GmbH.*

We have long taken for granted the use of electric power, but statistics show enormous differences in this respect between individual regions. In the USA, for instance, there is a hundred times more electric power per head than in China. Conditions in India are much the same as in China. Again, large areas of South America and Africa, and even parts of the USA, have no electric power supply whatsoever. One of the main reasons for this is that in these regions the only available road or railway network, as the case may be, is highly inadequate, and both the topography and the low density of population would make electrification a drawn-out and costly undertaking. For this reason, a new approach has been tried, and land lines laid by means of helicopters. This has happened in, for example, Puerto Rico and a hilly, wooded area of Virginia.

A Sikorsky S-58 helicopter completed this task in about one third of the time which would have been necessary using conventional methods. In addition to this, the overall cost of the operation was considerably reduced owing to the fact that it did not necessitate the construction of new roads or approaches.

The operation was conducted from a place accessible to vehicles, where concrete mixers and construction materials were assembled. In the first place, only a handful of men and tools were brought to the place where the pylons were to be erected; their task was to excavate or blow the hole for each pylon. On its second trip, the helicopter carried one and a half tons of liquid cement in a hopper to the site and loitered there in hover flight until the contents of the hopper had been poured into the pre-prepared hole. In the ensuing phase, the assembled pylon was carried, also as an external load, and let into the foundation (still wet) from the helicopter. Once all the pylons had been set up in this fashion, the helicopter completed the job by laying the actual cables.

These and similar operations carried out by conventional helicopters led to the idea of designing a helicopter intended from the very start as much for the transport of bulky external loads as for slaving in hover flight.

The idea is, in itself, as old as the helicopter, and the term for an aircraft of this type, namely one intended in the first place as a completely specialized vehicle, was soon hit upon, namely "crane helicopter" or "Flying Crane." The definition of the crane helicopter—the expression is often wrongly used to designate heavy conventional helicopters, which can of course also carry external loads—is "a helicopter of any size without an internal hold, which can land astride the load which is to be suspended from it or, whilst in hover flight, can lift it off completely inaccessible terrain by means of a cable winch."

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In the last two decades, numerous crane helicopters have been projected, designed, and, in some cases, even built. One can cite the design made by Professor Focke in 1940 for a hook load of five tons, the Hughes XH-17 (which at the time proved too ambitious in size) and the McDonnell XHCH-1, Model 120, also by McDonnell and with a payload of up to one ton, is impressive for its practicality and originality. Another small Flying Crane for a payload of some 1,300 lb is being manufactured by Omega. Using a Sikorsky S-56 dynamic system further developed, Westland in Great Britain has built the *Westminster* heavy turbine-powered load-carrying helicopter, which can transport a five-ton payload and, in its later version with gantry-type under-carriage, will be a Flying Crane, but with additional internal space. A gigantic Russian flying crane has recently been much spoken of; it is estimated capable of lifting a payload weighing up to 15 tons and has been derived from the Mil Mi-6. Like the *Westminster* crane type, this helicopter has a gantry-type under-carriage and a cabin in which persons or small cargo can be transported.

The last two types mentioned are Flying Cranes in the sense of the definition used above, despite the fact that they feature an internal hold. On account of its great height above ground, this hold is however difficult to load with freight and is thus, at the most, suitable only for the auxiliary transport of passengers.

Sikorsky, in particular, is intensively engaged on the development of heavy crane helicopters. In March 1959, the S-60 Flying Crane, derived from the well matured Sikorsky S-56 helicopter, flew for the first time. In the ensuing two years, this trial model proved the correctness of Sikorsky's crane conception. The development of a transport container system even makes it possible to take on the main tasks of the conventional helicopter, namely the carriage of passengers. Since a container of this type can be suspended almost free of vibration and well insulated against sound, and the design and size

Model of the WF-S64 with transport container attached.

The S-64 crane helicopter carrying a heavy caterpillar tractor to its operational site.

Prototype of the Sikorsky S-60 (two Pratt & Whitney R-2800 piston engines) with underslung passenger cabin.

of windows and doors is practically unrestricted, the passenger can even be offered a standard of comfort so far unknown in helicopter travel.

The appearance of powerful free turbines, which have been specially developed as powerplant for helicopters, has spelt a significant improvement in performance, safety, and profitability. "Weser" Flugzeugbau GmbH, in Western Germany, has participated in this development and is also planning series production at a later date, which would be carried out parallel to, and in close cooperation with, Sikorsky. The designation of this prototype is WF-S64 or, in the American version, S-64. The two versions show minor differences, which relate to instrumentation and equipment only.

The first prototype of the WF-S64 has almost reached completion and is to be subjected to extensive flight and airworthiness tests next year.

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The research, design work, investigations, and test programmes involved in bringing this helicopter to its present state of development are very complex, and space considerations rule out a detailed description in this article. All that can be done here is to pick out some of the most important design considerations which are at the same time typical of a helicopter of the Flying Crane class.

1. A key question influencing the design is whether the machine is to be used purely for crane-type operations—i. e. those carried out during hover flight and combined with "ultra-short" hauls (distances up to a dozen or so miles) —or whether it is desirable to extend the scope of the helicopter to include the transportation of bulky external loads over greater distances of, say, up to 200 miles. Examples of pure crane work are the posing of a component of a bridge, use in the construction of a dam, or transportation of timber to a nearby river for floating down.

Both thorough commercial market research and military appreciations have however shown that, by accepting relatively small losses in its usefulness for typical crane operations, the helicopter's overall field of application can be extended, so that the transport of external loads can be effected over greater distances and a long ferrying range achieved.

The Flying Crane then becomes not merely a tool for the military engineers but also has its place in the overall supply system. In the civil field, it is, for example, possible to transport a "flying operating theatre" to the scene of a catastrophe and set it down there, after which the crane is still available for clearing and similar operations.

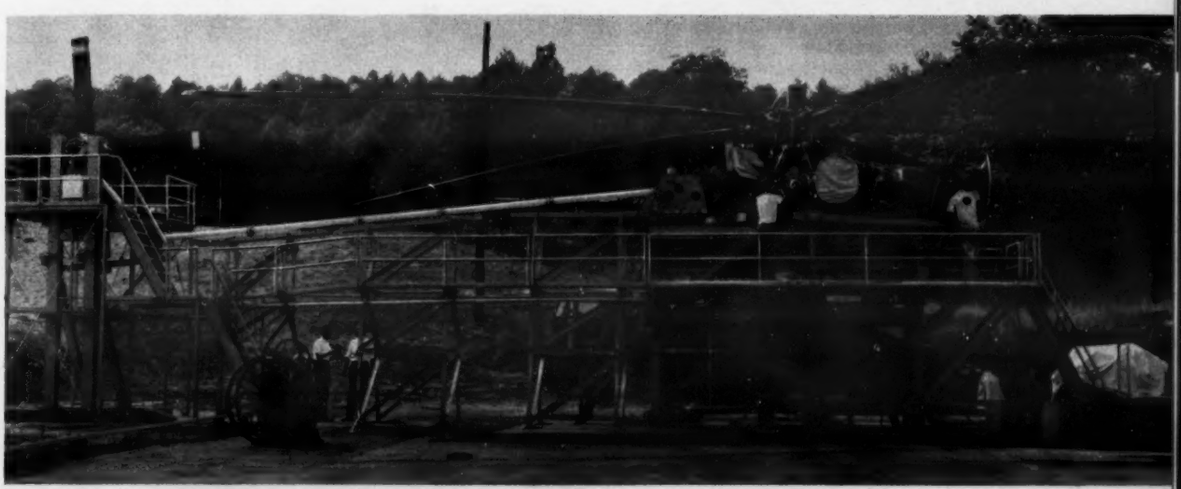
There are thus two main categories of application to be differentiated and taken into account during design, the use of transport containers being a sub-division of the second category. The effects on the design are evident: high speed and low fuel consumption play a minor part in the first category, but in the second these factors largely determine whether the helicopter is profitable, and its usefulness. The basic design—single or multi-rotor, blade tip or shaft propulsion—and also details such as instrumentation, navigational equipment, and aerodynamic efficiency of the non-stressed parts, are highly dependent on the multiplicity of functions desired.

2. Another essential requirement for the Flying Crane is extreme ruggedness; in other words, it must be largely independent of ground equipment and organization, be simple to maintain, and stand up well to rough work. The latter demand tends to curb the desire to plunge ahead into new technical fields, since it necessitates the maximum possible use of tested and proven components, whose life and behaviour in operation are reasonably predictable.

3. A crane helicopter designed to give only a certain performance under sea-level, standard day conditions is hardly likely to enjoy success with the users. The effects of high altitudes and high external temperatures can impair the efficiency of a helicopter to the extent of making it impossible for the vehicle to carry out its operations without drastic reduction in payload. Since mountain operation of the crane helicopter and its employment in sub-tropical, tropical, and sub-polar regions of the earth seem of particular interest, they must be taken into consideration from the very beginning. This has a particularly important bearing on the choice of powerplant.

4. Lastly, operating costs both for ultra-short haul and longer-haul transport must be attractive enough, as compared with conventional transport and heavy equipment, to justify the use of the Flying Crane. Maximum payload capacity, minimum maintenance costs per flying hour, and versatility in operation are, accordingly, the targets.

5. Some of the other requirements affecting design are a direct view of the aircraft, the load, and the terrain below for the pilot; maximum safety while the cargo is being picked up; and the most effective devices possible for quick and simple loading.



On this test stand at the Sikorsky Division of United Aircraft, the entire dynamic system of the S-64, namely turbo-engines, reduction gearing, main rotor, propulsion shaft, and tail rotor, are subjected to thorough testing.

The next section will show that a healthy compromise, answering all these diverse requirements, has been found in the WF-S64.

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The design and construction of the WF-S64 crane helicopter emerge from the illustrations and the detailed characteristics (see box). The following remarks are therefore limited to those aspects of the Flying Crane's design which seem important in relation to the fulfilment of the tasks it is called upon to carry out.

As mentioned earlier, there was a clear-cut basic decision in favour of a helicopter with as wide a field of application as possible. This led to the selection of the single-rotor design with economic shaft propulsion by means of free turbines, meeting requirements 2, 4, and 5 above. Another decisive consideration was that, as helicopters grow in size, more and more vibration problems arise, whereas in smaller helicopters they are either absent or easy to solve. Among these problems are questions such as the effect of low-frequency turbulence and periodic forces on the airframe due to the fluctuating downwash from the highly-loaded rotor.

Experience in these matters was provided by the S-56 and the S-60 helicopters, which are in the same size range. By using fundamentally the same design, development risks were reduced to a minimum, as were the time and costs involved in prototype and series construction.

View inside the S-64 cockpit. In front of the pilots is the instrument panel with the flight and engine monitoring instruments; in the centre, between the two pilots, are panels with control switches for the winch and the freight hook, the automatic stabilization system, the fuel feed system, the R/T equipment, and the navigational aids.

The gantry-type design of airframe and undercarriage is designed to allow almost 10 ft clearance when the aircraft is on the ground. Laterally, this clear space is limited only by the undercarriage legs and by the very low-set cockpit. From this vantage point, the load-pilot has an excellent view of the main undercarriage, the loading equipment, and the personnel working on the ground. He is thus in a position to make really "fine adjustments." The ground clearance and the width of undercarriage are such that, about 85 times out of 100, it is possible to land directly astride the load and thus avoid uneconomical hover flight. This makes for safer loading, less time is required, and the exposure of ground crews to rotor downwash is minimised. A ground vehicle can drive directly under the load-supporting gear to transfer its load, or can even be slung and transported complete with load. The external load being mostly shielded from the wind by the pilot's cabin, the drag of fuselage plus load is relatively small. As a result, higher cruising speeds can be attained than with helicopters of conventional design, with their dangling loads.

The cockpit and the load pilot's cockpit *(right)* of the S-64 helicopter. The load pilot is provided with his own control stick and control panel operating the crane winch, etc.

The very favourable 0.53 load to all-up weight ratio is not only due to the low weight per horsepower of the turbines (about 2.2 lb/h.p.), but also stems from a light-weight fuselage configuration. In other words, this helicopter can lift more than its own weight. A hydraulically-driven winch with a 135-ft long cable can raise the full payload of 8 tons up to the fuselage during hover flight. A number of attachments for fastening the load-supporting cables are fitted at each side of the fuselage and on the undercarriage; to these, loads can be secured simultaneously by a number of cables, which means less vibration and prevents the load from rotating. The same attachments are used to fix on the cargo containers. For taxiing, for the attachment of a cargo container, or for landing at forward speed, it is necessary for the load to be lifted off the ground, as long as the helicopter is not airborne. For this purpose, the legs of the undercarriage can be hydraulically shortened by 8 in and then extended again after attachment of the cable; this system has been dubbed "the knee" and it eliminates the necessity for lever devices, loading devices on the ground, and tiresome work on the part of the loading gang.

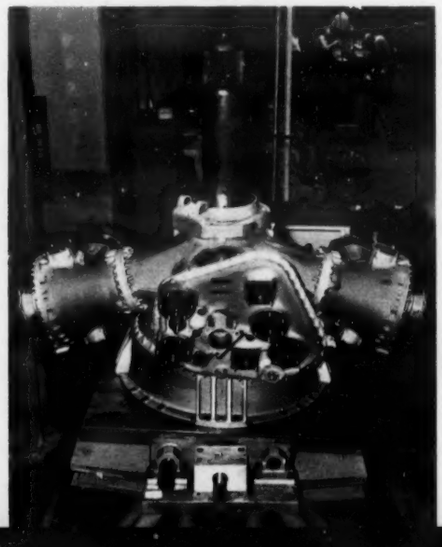
Unlike the S-60, which had a rotating seat with adjustable control stick for the co-pilot-cum-load-pilot, the co-pilot in the WF-S64 switches to the fixed load pilot's seat facing aft. The helicopter can, however, also be flown with three pilots. By means of a control stick on the right, at the arm rest position, yaw, pitch, and roll controls can be activated by the automatic stabilization equipment (ASE), as can a reserve electrical circuit. This arrangement, which saves both weight and space, permits a better vertical downwards view since there are no pedals to restrict the field of vision. The normal ASE is complemented by a load stabilizer.

The instrument panel, located in the field of vision of the pilot seated at the front, contains the normal flight and engine monitoring instruments and the indicators for the usual navigational equipment. In addition, there are indicators for the length of winch cable and a direct reading for the cable tension. An indicator gauge for towing operations has been specially developed, and this shows the pilot the angle between the direction of the towing cable and the horizontal axis of the fuselage. One other new instrument should be noted, namely an indicator for flow breakdown on the retreating blade, which is a valuable aid to the pilot.

On the ground, a small gas turbine supplies power for all the hydraulic, electric, and pneumatic systems and serves to start the main powerplant. The following example illustrates how the requirements of sturdiness and independence of ground-based installations have been met.

After several attempts to start an engine in cold weather, the battery all too often goes dead. To obviate breakdowns of this kind, the auxiliary engine is fitted with magneto ignition; if this latter ignition system should fail, recourse can still be had to flare ignition device for starting.

The S-64's main rotor gear mechanism with both angled gears and the vertical main rotor shaft.

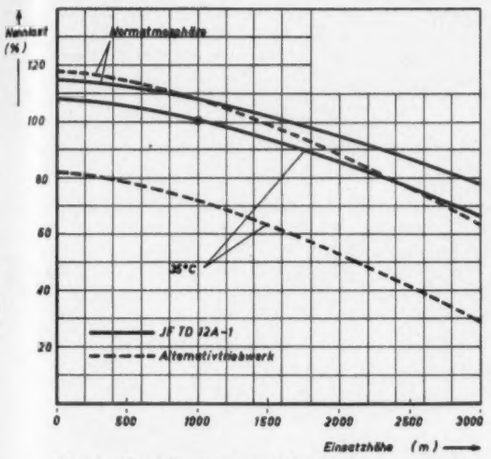


Characteristics of the WF-S64

Crew	2 pilots 3 other crew members
Powerplant	
Number	two
Designation	JFTD12A-1
Compressor	JT12A-5
30-min rating (take-off rating)	4,110 h.p.
Max. continuous rating	3,245 h.p.
Shaft rotation speed	9,000 r.p.m.
Manufacturer	Pratt & Whitney (SNECMA licence)
Dimensions	
Overall length	87 ft 5 in
Overall width	72 ft 0 in
Overall height	24 ft 3 in
Width, excluding main rotor	21 ft 10 in
Height (tail rotor blades tilted at 45° to horizontal)	22 ft 2 in
Wheelbase	24 ft 5 in
Ground clearance to rotor blade tips	11 ft 6 in
Fuselage length without tail rotor	70 ft 3 in
Ground clearance to underside of fuselage at take-off weight	10 ft 6 in

	Main Rotor	Tail Rotor
Number of blades	6	4
Diameter	72 ft 0 in	15 ft 0 in
Rotor sweep area	4,070 sq ft	177 sq ft
Rotation speed	185 r.p.m.	833.3 r.p.m.
Peripheral speed	696 ft/sec	654 ft/sec
Blade area, each	71 sq ft	8.4 sq ft
Blade width	24 in	13.5 in
Solidity ratio	0.1046	0.1905

Weights	
Hook load	17,640 lb
All-up weight	38,070 lb
Rotor disc loading	9.36 lb/sq ft
Ratio of horsepower to gross weight at short-duration output of 5,480 h.p.	0.144 h.p. lb
Ratio of useful load to gross weight	0.53
Performance	
(at standard atmosphere, 3,300 ft altitude, frontal area of external load 130 sq ft., nominal load)	
Rate of climb	vertical: 485 f.p.m. oblique: 1,500 f.p.m.
Cruising speed	95 kts
Range, at 20 kt headwind	540 n.m.
Maximum cruising speed with aerodynamically favourable container	145 kts
Ferrying range	675 n.m.
Ferrying, partly on one engine	863 n.m.



Nominal load (in percentage) of the S-64 crane helicopter versus altitude (metres) and external temperature, this for two different powerplants. The unbroken curves refer to the Pratt & Whitney JFTD12A-1 turbo-engine, the dotted curves to an alternative engine. A typical operation was used as the basis for these calculated values namely: altitude 1,000 m (3,300 ft), headwind 37 km/h (23 m.p.h.); fuel reserves 10 percent; radius of action 40 km (25 miles); frontal area of external load 12 sq m (13.0 sq ft).

The auxiliary engine is started by a hydraulically-driven motor, fed from a pressure tank which can be refilled by means of a hand pump, so that in an emergency any number of attempts can be made to start the engine.

In the design of the WF-S64, moreover, the desire for sturdiness and for long intervals between maintenance has been fulfilled by incorporating to the maximum possible extent the proven series components of other types. The main rotor blades, control system components, and the entire tail rotor system have been taken over from the S-56 or S-60. The testing programme for individual components and the entire dynamic system was consequently able to start very early, long before the actual prototype could be tested.

On the other hand, the main gearing, with rotor shaft, angled gears and auxiliary equipment, had to be developed from scratch, although recourse could be had to considerable accumulated experience. In the first stage, the gear transmits an input power of 5,400 h.p. Each of the angled gears can, should the other fail, transmit the entire engine power to the main gear mechanism.

After extensive investigations, two Pratt & JFTD12A-1 free turbine engines were chosen; take-off power is at present still de-rated to 4,050 h.p. each, but this can be maintained for 30 minutes (for details of this engine, see *Interavia* 7/1961). The maximum power output required of the rotor is considerably less than the installed engine power, so that a respectable reserve is available for operation at high altitudes and at high temperatures. The graph shows the effect of altitude and temperature on the output of the installed engines, as compared to other propulsion units whose rating only slightly exceeds the required rotor power. At altitudes of up to 3,300 ft, weaker powerplant, with its lower engine weight and fuel consumption, enables a somewhat larger payload to be carried. At higher altitudes, however, stronger turbines come into their own and give a distinct advantage in terms of increased payload. At 9,000 ft, payload is 11 percent higher. These advantages are even more pronounced, if payloads feasible at an external temperature of +35°C are compared. Since ideal conditions seldom occur in practice, engines were selected which allow greater overall economy in operation.

One important result of the very considerable excess power is increased safety in case of the failure of one engine; flight can be continued at full take-off weight. The future take-off rating of 4,600 h.p. per engine will even be sufficient to set down the full payload during hover without damage, provided that exterior temperature and flight altitude are not too unfavourable. In an extreme emergency, the load can be rapidly jettisoned.

The careful coordination of rotor and powerplant allows the Flying Crane to carry out long-distance missions economically and successfully, besides its special crane operations. Thus, for example, 45 passengers can be carried in a transport compartment over distances up to 280 miles (including 20 minutes fuel reserves), or alternatively, 60 fully-equipped soldiers over a distance of about 125 miles.

In ferrying flights from one operational area to another, the helicopter can—after using up one ton of fuel—be flown on one engine without overloading the other, so long as it flies at a safe altitude. In this manner, the ferrying range increases from about 780 to about 1,000 miles.

*

The typical crane operations described at the beginning of this article were successfully carried out by conventional helicopters, but the crane helicopter described here can perform the same task in a fraction of the time, at half the cost per ton-mile and, most important, with greater safety. It exploits more fully the helicopter's special capabilities of both vertical take-off and work during hover flight. Thus, new fields of activity which until now seemed the preserve of ground transport, whether civil or military, have now been opened to aviation. The crane helicopter cannot, in the long run, be replaced by any other VTOL aircraft.

The special uses already established are so numerous that only a selection can be listed here:

Towing immobilised vehicles;
Towing ships;
Transport and unloading supplies or building materials;
Loading and unloading ships;
Laying cables and pipelines;
Fire-fighting;
Emergency supply of drinking water to distressed areas;
Mine clearance;
Submarine detection;
Airborne radar applications;
Air launching of aircraft or missiles;
Recovery of costly booster rockets and space capsules;
Civil defence duties.

Container applications include:

Passenger and troop transport;
Mobile operating theatres, signals centres, field workshops, etc.

Some of the numerous new ideas for the crane helicopter's use which constantly crop up will prove impracticable, but many will further broaden the range of its applications.

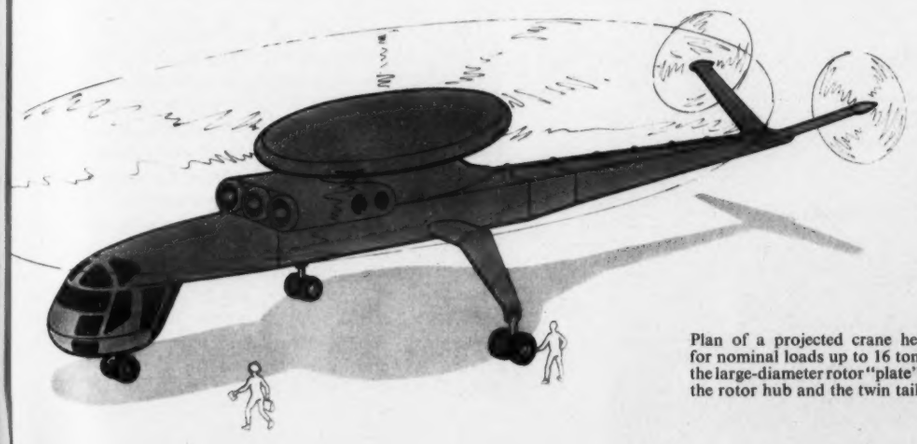
*

Although the WF-S64 Flying Crane is not yet operational, heavier payloads are already being called for. The next stage in development will be a flying crane which will have a range of 230 miles with a 16-ton payload. In this helicopter it will be possible to incorporate the WF-S64 rotor blades with only minor modifications. The 100-ft rotor diameter will be achieved by considerably increasing the space between the blade joints; one of the advantages of this is that eleven or more blades can be mounted around the circumference of this "rotor disc". By using twin tail rotors, overall dimensions can be reduced and WF-S64 components retained.

Design of a hypothetical crane helicopter for nominal loads up to 40 tons. This helicopter could easily carry long-range, multi-stage ballistic missiles.

There remains the latest "Super helicopter" on which the project office is currently working. This is the Flying Crane shown in the last illustration, with a 160-ft rotor and capable of transporting a 40-ton load of outsize dimensions.

The helicopter has now emerged from the pioneering stage and we are at the threshold of the development of the crane helicopter. No one can foresee what impetus the crane helicopter will give to those industries which have, until now, been handicapped by limitations on the dimensions of their products. It is conceivable that completely new enterprises will spring up, for example factories which produce prefabricated houses in the form of a few construction units for transport by helicopter to the building site and final assembly on previously prepared foundations. But that day is, admittedly a long way ahead. ←



Plan of a projected crane helicopter for nominal loads up to 16 tons. Note the large-diameter rotor "plate" around the rotor hub and the twin tail rotors.

The Westland Wessex

As a result of the mergers and regroupings that have taken place within the British aviation industry, Westland Aircraft Ltd. has absorbed Fairey Aviation, Saunders-Roe, and the helicopter interests of Bristol Aircraft Ltd., and has emerged as the largest helicopter constructor in Europe. At present there are five rotary wing aircraft either in development or production within the company, and three of these are designs which were taken into the Westland programme as a consequence of the mergers.

The remaining two aircraft, the *Whirlwind* and the *Wessex*, cannot be described accurately as original Westland designs but are products of the policy which the company has followed since the end of the second World War. Although Westland entered the rotary wing field in 1934, and accumulated a background of experience in this type of flight, it was after the cessation of hostilities that the company entered into an association with Igor Sikorsky and commenced the production of Westland helicopters based on the proven flight and engineering principles of Sikorsky.

With this technical liaison as a basis, the company has been able to take over a number of successful designs, develop them to British standards and fit British engines and equipment. A further advantage of the association is that it has made available to Westland such proven components as rotor heads and gear boxes which have millions of hours of flight operation behind them. This has obviated costly and time-consuming development programmes for these special components.

Stemming from the requirements of both civil and military operators, the general trend in helicopter design in recent years has been towards larger machines capable of carrying either a larger number of passengers or a heavier military load. This trend is normal and has been demonstrated in the development of fixed wing aircraft. Until fairly recently, it was possible to meet these demands for increased performance by greater installed power. The large helicopter, arriving as it does at this particular moment in history, now encounters a particular problem. With the increasing use of rotary as opposed to reciprocating engines in aviation, the piston engine developing more than 1,000 h.p. is becoming less readily available, and helicopter constructors are turning to the gas turbine to provide the higher powers demanded for improved performance.

In these circumstances, the change toward turbine engines has been dictated basically by the lack of suitable piston engines. A comparison of the two types of powerplant indicates that turbine power is likely to be more expensive than equivalent piston power, but certain characteristics of the turbine offer marked advantages which offset the cost. The fuel consumption of the turbine is higher than that of the piston engine but it uses cheaper and safer fuel. This increased consumption and the need for greater fuel tankage is offset to a certain extent by the fact that the turbine installation can be at least 25 percent lighter than the piston engine.

When comparing the relative merits of the two types of power source, it is essential to consider the type of operation for which the helicopter is to be employed. The consumption figures for the supercharged piston engine and the turbine are very similar if high power outputs are required. A typical example would be the need for hovering power in a submarine search operation. In the cruising condition the supercharged piston engine can show some advantage when it is operated in the weak mixture range to obtain endurance, but this entails low forward speeds. The turbine on the other hand is better when operated at higher power outputs and speeds in order to obtain the benefit of the reduced specific fuel consumption, and this is reflected in improved range figures, particularly in head wind conditions.

The first application of turbine power to a helicopter by Westland was undertaken in 1956. This conversion started with the purchase of an American Sikorsky S-58 which was powered by a Wright R-1820 *Cyclone* piston engine, giving 1,525 h.p. This engine was removed and a Napier *Gazelle* NGa. 11, delivering 1,120 s.h.p., installed in its place. Engine running commenced in March, 1957, and in May of the same year, the aircraft made its first flight. After the initial flight tests, the engine was replaced with a developed version of the *Gazelle*, the NGa. 13, giving 1,650 s.h.p., and this engine is now the standard powerplant in the Westland *Wessex 1* helicopters in quantity production for the Royal Navy.

The all-metal main rotor blades can be folded alongside the fuselage and the tail unit swung forward to reduce storage space required to a minimum. Connection and disconnection of the tail rotor drive and controls is completely automatic.

The Napier Gazelle

The design of this engine was started in 1954 under a Ministry contract, and a 1,000 hours type test was completed in 1957. In configuration the engine has a single shaft with an eleven-stage axial compressor, two-stage compressor turbine, and a single-stage free power turbine. A gearbox and torquemeter receives the drive from the power turbine and reduces the shaft speed by 7 : 1 through an epicyclic gear train. The gearbox output speed is then the same as that of the original piston engine in the S-58.

The *Gazelle* has been designed to operate at any angle, and this facilitated installation in the *Wessex I* at the same inclined angle as the piston engine. The only major installation problem was that of reversing the output rotation of the engine. As the *Gazelle* is a free turbine, the change of nozzle vanes and power turbine blading was a fairly simple operation and involved no performance penalty. In fact, this modification offers an advantage, in that the contra-rotation of the compressor and power turbines reduces the gyroscopic moments in the engine.

The free turbine also offers considerable flexibility in operation. Normally the free turbine output is limited at a predetermined torque, which may be either an engine or a transmission limitation. The fixed turbine on the other hand is limited by turbine inlet temperature, and if the engine is overloaded by over-pitching, for example, the engine and rotor speeds are reduced while the fuel/air ratio increases, resulting in increased temperatures and possible engine damage. Similarly, with the free turbine there is less danger of exceeding engine limitations when extra power is demanded by the rotor owing to external conditions such as gusts. With the free turbine there is a reduction in rotor r.p.m., but with the fixed turbine this is accompanied by an increase in turbine inlet temperature and possible compressor surge. The turbine inlet temperature can be controlled by a safety device in the fuel metering system in these conditions, but the compressor surge presents a considerable problem.

The development of the *Gazelle* engine has progressed from the original 1,250 shaft horse power to the present rating of 1,650 s.h.p. on the NGa. 13, the engine which is at present in production for the *Wessex I*. This represents a rating of 1,210 s.h.p. for maximum continuous power, 1,465 s.h.p. for 1 hour and 1,650 s.h.p. for 2½ minutes emergency power. Further developments are planned, including an introduction of new turbine blade material to permit higher gas temperatures which will increase the maximum power output to 1,750 s.h.p. A further developed engine designated NGa. 18 with a larger compressor will be available next year and will be installed in the *Wessex III*. This engine will have a maximum rating of 2,000 s.h.p. and a one hour rating of 1,750 s.h.p., but to match the transmission system of the *Wessex* it will be torque restricted to 1,540 s.h.p. This torque restriction limits the power delivered to the transmission system at sea level, but provides a compensation for loss of engine power due to increased altitude and ambient temperature and can be regarded as a power reserve.

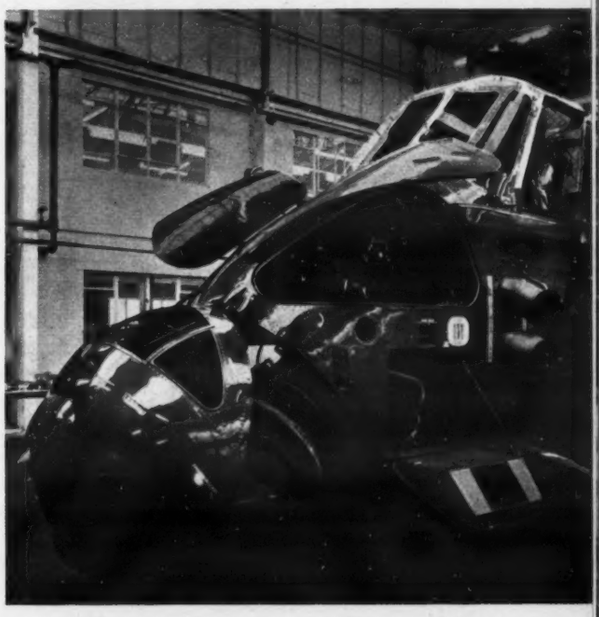
All these engines are of the same overall dimensions and are interchangeable, the power increases having been obtained by internal modification. A development of the *Gazelle* to a 3,000 s.h.p. rating is in hand, but this will be achieved by the addition of an extra stage to the compressor. This last engine therefore will not be interchangeable with its predecessors without modifications to the engine bay.

The feature of interchangeability is one which has been pursued throughout the engine design. The engine structure can be subdivided into seven major units. These are: the intake casing and auxiliary drives; the axial compressor; compressor support plate; combustion system; compressor turbine; power turbine; and gearbox with torquemeter. By this system, each unit can be built, tested, and serviced separately and is interchangeable with any other of the same type. In service this enables units to be overhauled separately so that the full benefit can be derived from the inherent long life of items such as the compressor and gearbox. It also enables a simplified spares and support organization and a unit exchange spare parts service to be employed. This is of particular value to both civil and military operators, as the spares holding and accounting is both reduced and simplified.

The application of turbine power also offers a number of other advantages. The *Gazelle* installation in the *Wessex* is 770 lb lighter than that of the piston engine, and the transmission clutch required with the piston engine is eliminated by the free power turbine of the *Gazelle*. This weight saving can be utilised, if required, for increased fuel tankage. The reduction in engine vibration reduces fatigue in the airframe and equipment and also reduces the discomfort for the crew and passengers in long duration flights.

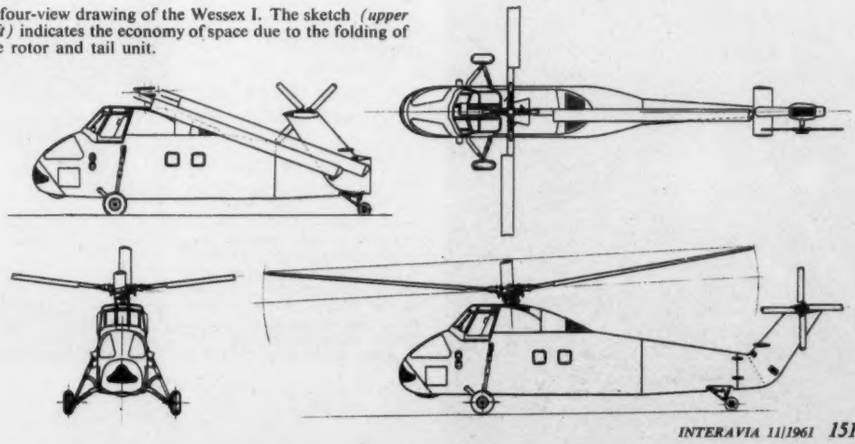
Operationally, the use of turbine power provides at least one major advantage. The time required for engine warm-up after starting is negligible. With the piston engine, this period

The *Gazelle* installation in the *Wessex I*. The hinged access doors and built-in servicing platform facilitate maintenance in the field.



◀ The coupled *Gnome* H.1000 engines installed in the Wessex II airframe. The angled installation leaves considerable free space in the fuselage nose above the engines for an electrical and radio bay.

A four-view drawing of the Wessex I. The sketch *(upper left)* indicates the economy of space due to the folding of the rotor and tail unit.



A detailed view of the tail rotor hub, showing the centrally operated spider, which changes the pitch of the tail rotor blades for directional control.

took a considerable time—something over ten minutes from cold. With the turbine, this time is under a minute, apart from cockpit checks, and if the pilot is waiting at readiness in the cockpit, the aircraft can start from cold and take-off in 30 seconds. For naval operations, this rapid response is of obvious value and it is feasible that in future the planeguard helicopter, which remains airborne during flying operations from an aircraft carrier, will be able to wait at readiness on the carrier deck. This represents a considerable economy both in aircraft and aircrew utilization.

The Wessex Airframe

The general configuration of the *Wessex* is well known, and the Naval variant differs from the standard chiefly in the specialised equipment installed. For the anti-submarine warfare role, provision is made for search equipment such as an Asdic installation and associated items. The whole of this equipment can be rapidly dismantled and removed through the cabin door if the aircraft is to be converted for other duties.

To enable the aircraft to carry out its anti-submarine role of search and kill under most weather conditions and by night or by day, it is essential to provide the pilot with automatic assistance. The degree of close control and accuracy of operation demanded in the various aspects of anti-submarine warfare, and the lack of datum for hovering and maintaining level flight under conditions of darkness and bad weather, make automatic aids completely vital to the success of the operation.

In general terms, the anti-submarine operation can be viewed in three phases. Firstly, the period of cruise to the operating area; secondly, the positioning at the hover and at the right height at which the search is to commence; and finally, the actual search operation. These are known as the auto-pilot mode, the radar mode and the ASW mode respectively.

In the first mode the operational flight to the search area is carried out under auto-pilot conditions in which a three-channel system automatically monitors a predetermined flight plan in terms of altitude, pitch, roll, and yaw. In effect, these channels provide similar answers to those from the conventional auto-pilot. In this particular case, a vertical gyro is the prime mover for causing signals to be passed through an electronic system, so that deviations from the correct pitch and roll planes are automatically rectified by adjustment of the rotor servo control units.

Deviations from a pre-set cruise heading are rectified in the yaw channel, a gyro compass unit being wired into an electronic circuit linked to the servo motor system. In the altitude channel, barometric variations from a given altitude datum are sensed, causing a mechanism to be operated which passes signals through the electronic channel linked to the servo control system so that the required pre-set altitude is maintained.

On reaching the search area, the radar mode is brought into operation, and the aircraft automatically descends to a pre-set height, which is established and then maintained through a radar altimeter coupled into the automatic control system. The aircraft is brought to the hover by signals emanating from a doppler aerial system coupled into the automatic control system.

Once the aircraft is on the station at the right height and at the hover, the sonar buoy is lowered into the water by the sonar operator winding out the cable drum. Electronic devices on the cable drum and in the sonar buoy are related to establish the length of dry cable, and

The Westland Wessex I and II

Dimensions	Both types
Overall length	65 ft 9 in
Overall height at tail rotor	15 ft 10 in
Overall height at main rotor	14 ft 3 in
Main rotor diameter	56 ft 0 in

Performance	Wessex I Based on ISA conditions and 12,600 lb AUW at SL	Wessex II Based on ISA conditions and 13,500 lb AUW at SL
Max. speed	115 kts	120 kts
Economic cruising speed	100 kts	100 kts
Max. range, standard tankage	340 n.m.	300 n.m.
Rate of climb at SL and 60 kts forward speed	1,750 ft/min	1,500 ft/min
Rate of climb, one engine out (1 hour contingency power)	—	940 ft/min
Hover ceiling in ground effect	7,000 ft	16,500 ft
Hover ceiling out of ground effect	5,000 ft	10,000 ft
Fuel consumption		
Economic cruise consumption	90 gal/hr	103 gal/hr
Hover consumption	110 gal/hr	130 gal/hr

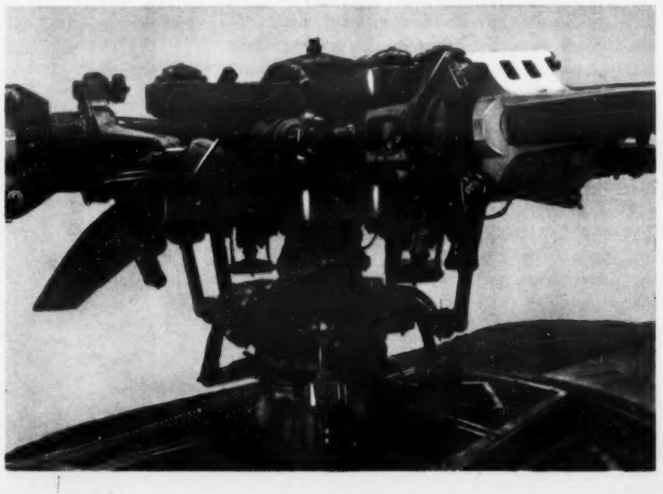
Comparative Costs of Turbine and Piston-engined Helicopters

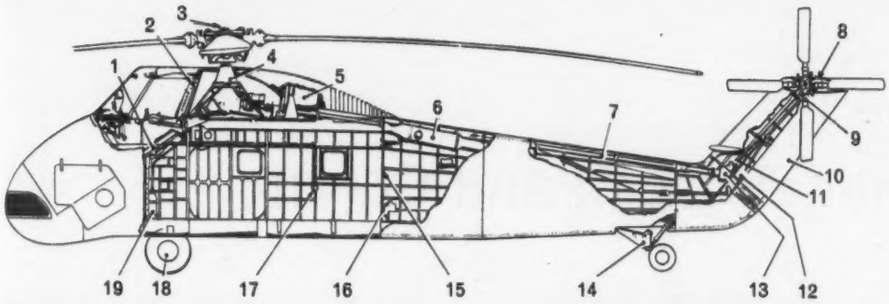
	Wessex I (Wright Cyclone R.1820) (£)	Wessex I (Napier Gazelle N Ga.13) (£)	Wessex II (Gnome H.1200) (£)
Cost of aircraft with engine	4,450,000	5,500,000	6,400,000
Optional equipment	425,000	425,000	425,000
Aircraft spares	890,000	1,100,000	1,280,000
Engine spares	116,250	224,250	369,000
Spare engines (25)	387,500	747,500	950,000 (50 off)

The table above illustrates the comparative costs in £ sterling of piston-engined and turbine-powered helicopters, and is based on the purchase of 50 aircraft and support equipment. The aircraft spares include airframe, instruments, and electrical spares, major aircraft transmission units and ground equipment. The figure for engine spares is based on the assumption that major overhauls will be carried out by the manufacturers.

The main rotor head, with the flapping and drag hinges. Droop and anti-flapping restrainers prevent blade "sailing", and make starting possible in gusty winds. As the rotor speed increases, the restrainers are released by centrifugal force.

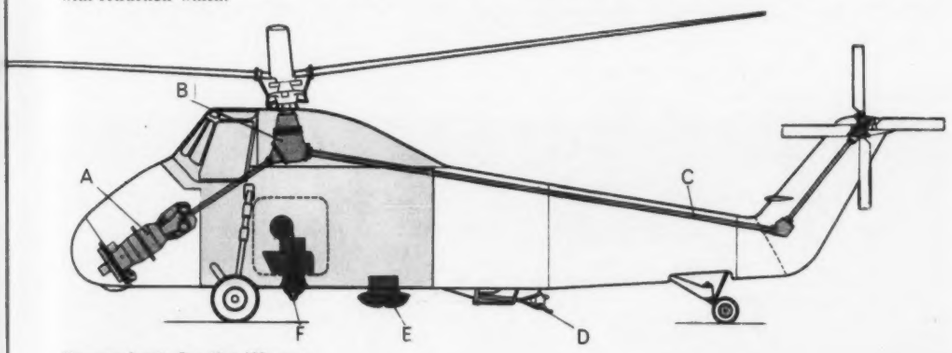
The main rotor head before the blades are fitted. Both the cyclic and collective pitch controls are servo-assisted, the servo control being duplicated. Separate hydraulic pumps and systems are provided for each set of jacks, ensuring that servo assistance is available during autorotation and starting.





Structural details of the Wessex 1
1 – Main drive shaft.
2 – Oxygen supply connection.
3 – Main rotor.
4 – Main gearbox.
5 – Transmission oil cooler.
6 – Heater.
7 – Intermediate drive shaft.
8 – Tail rotor gearbox.
9 – Tail rotor.
10 – Tail pylon.
11 – Tail rotor drive shaft.
12 – Directional pitch control.
13 – Intermediate gearbox.
14 – Tail undercarriage.
15 – Cabin rear bulkhead.
16 – Pressure refuelling point.
17 – Cabin oxygen supply points (three per side).
18 – Main wheels.
19 – Oxygen system.

"X-ray" of the Wessex AWS version. Left to right: A – Napier *Gazelle* turbo-engine; B – main rotor gearbox; C – drive shaft to tail rotor; D – quick disconnection towing device; E – Doppler radar antenna; F – sonar buoy with retraction winch.



Powerplants for the Wessex

	Napier Gazelle NGa.13				DH coupled Gnome H.1200
Dimensions					
Overall length	70 in* approx. according to exhaust				54.8 in
Max. width	33.5 in*				—
Nett Dry weight	835 lb*				approx. 1,030 lb
Performance ratings	SL.Standard atmosphere. 15°C		SL.45°C		
	s.h.p.	Spec. fuel consumption lb/s.h.p./h	s.h.p.	Spec. fuel consumption lb/s.h.p./h	Total s.h.p.
Max. contingency (2½ min)	1,650	0.677	1,325	0.736	2,700
Max. contingency (1 hr)	1,465	0.686	1,145	0.754	2,500
Max. continuous	1,210	0.711	920	0.800	2,100

* with radial intake and reduction gear

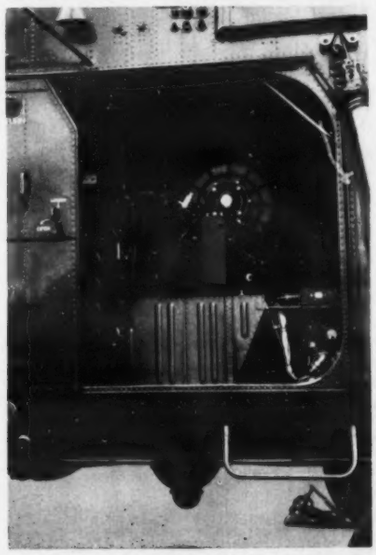
any deviation from pre-set cable length (i. e. hover height), causes a signal to be sent to restore the aircraft to its right height. In order to maintain accuracy, it is essential that the cable remains vertical. This is achieved by passing the cable through a fork mechanism which, when touched by the cable, causes a signal to be sent to rectify the aircraft position in the manner necessary to restore verticality of the cable.

Throughout all these operations, the various control devices are linked to the main auto-pilot system, which throughout the operation assists in maintaining the aircraft in its correct roll, pitch, and yaw planes.

Apart from anti-submarine duties, the naval helicopter may be called upon to fulfil a variety of other roles. These include air/sea rescue, minesweeping, and towing. In all these applications the automatic stabilization equipment is essential to the operation. At the recent Farnborough Show, the *Wessex* demonstrated its towing capability by hauling a train of military vehicles with a combined weight of over 50 tons. This demonstration was made with the aircraft stabilized at a pre-set altitude by means of the stabilization control, so that the angular drag of the tow-rope was compensated for automatically as the load increased. In the course of the demonstration, it was apparent that the aircraft altitude did not vary as the load increased, and it formed a convincing illustration of the ability of an automatic pilot to sense changing flight conditions and make the appropriate control commands, both earlier and more smoothly than a human pilot.

The growing importance of the helicopter in anti-submarine warfare is due to increased capacity and weight-lifting ability. Development on these lines is being steadily pursued at Westland with the installation of more powerful engines in later marks of the *Wessex*. The *Wessex II* is powered by two coupled de Havilland *Gnome* engines giving an installed power of 2,500 s.h.p., while the *Wessex III* fitted with a Napier *Gazelle* of 3,000 s.h.p. is under development. The twin-*Gnome* installation is indicative of the trend towards greater reliability in operation by giving the aircraft an engine-out flight capability. This trend is also shown by the development of the 512 series *Gazelle*, with axial intakes and exhausts, which can be mounted horizontally on the top of the fuselage. A possible layout for a future helicopter might incorporate two of these engines mounted in the rotor pylon with a combined drive and freewheel. Such a layout would offer the advantages of minimum length transmission shafts and an unencumbered cockpit and cabin, together with twin engine reliability.

Whatever the configuration of future helicopters may be, it is obvious that the turbine engine has clearly demonstrated its suitability as a helicopter powerplant and has ousted the piston engine from this duty. ←



The sonar winch installed in the cabin of the Wessex. When retracted, the sonar buoy fits into a fairing in the underside of the fuselage.

Close up of the sonar buoy and winch as installed in the Wessex. A fork encircling the cable senses any deviations from the vertical when the buoy is dipped, and a signal is passed to the auto-stabilization equipment to restore the aircraft's position. The system consists essentially of an electro-acoustic transducer, which can be remotely raised/lowered by a cable hoist and, when in the water, rotated from within the helicopter. In addition to normal visual and aural target data, readings are given of azimuth and submerged depth, as well as of the helicopter's height above the water.

The School for Flying is the Sky

The Canadair CL-41 and CL-41R

Now that fighters capable of Mach 2 upwards have reached the production stage and are, in some cases, already in service with the air forces of various countries, the problem of training the pilots for high performance aircraft is becoming increasingly acute. True, the electronic flight simulator can, to a certain extent, perform the task of preparing the new generation of pilots for their future tasks in flying such types as the Dassault *Mirage III* and *IV*, the English Electric *Lightning*, the Convair F-106, and the Lockheed F-104 *Starfighter*. But their usefulness is, plainly, confined within the limits of their capability. In other words, whereas training carried out on the ground can save the student many hours "at the control stick" and this helps to reduce costs, even the best simulator cannot in the last analysis entirely replace training «in the sky».

Many aircraft constructors seek the solution to the training problem in two-seat versions of single-seat combat aircraft, but compromise solutions of this nature sometimes involve burdensome expense on training in terms of cost per flying hour.

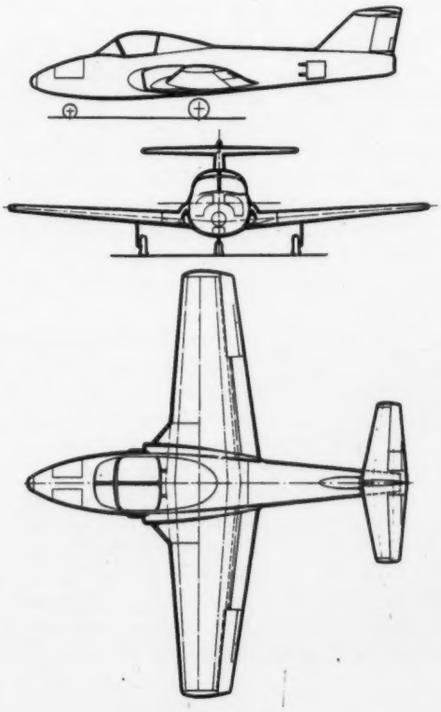
Some time ago, Canadair Limited (Montreal) — the Canadian subsidiary of General Dynamics Corporation in New York — which builds the Lockheed F-104G supersonic fighter under licence decided to develop a jet trainer which would be a vehicle not only for pure flight training, but also, where necessary, for instruction in a weapons system of the F-104G type. In the first place, Canadair built the CL-41 two-seat jet aircraft, designed primarily for pilot training. Two company-financed prototypes were constructed at the factory and, in January 1960, the first CL-41 was able to start flight testing. Once these tests were concluded, the model underwent thorough operational tests with the Royal Canadian Air Force. The CL-41 is used principally for the ab initio, but possesses qualities which make it very suitable for training through to the advanced level, preparatory to the supersonic fighter.

As the manufacturer emphasizes, the CL-41 has very straightforward flying qualities. For instance, rapid spin recovery is assisted by locating the fuel close to the centre of gravity in the fuselage. This not only eliminates the unfavourable effects of large moments of inertia around the longitudinal and vertical axes, but also the difficulties associated with asymmetrical fuel distribution, such as sometimes occur when fuel is stored in wing tanks.

Amongst the safety features to be found in the CL-41 design are a limit speed of 170 knots for operation of undercarriage and flaps — a figure which is high, relative to the stalling and operating speeds of this type of aircraft; engine air intakes protected by debris guards which extend automatically when the undercarriage is lowered; and an "annunciator panel" comprising individual lights to warn of fire, electrical failure, overheating, and like dangers; simple flying controls which are operated manually; good ditching characteristics; and reinforced longitudinal beams on the underside of the fuselage to ensure maximum crew safety in the event of a crash landing.

The Canadian Government has now decided to order the Canadair CL-41 jet trainer in series for the RCAF, but details as to the contract price of the 190 aircraft in question have so far been withheld.

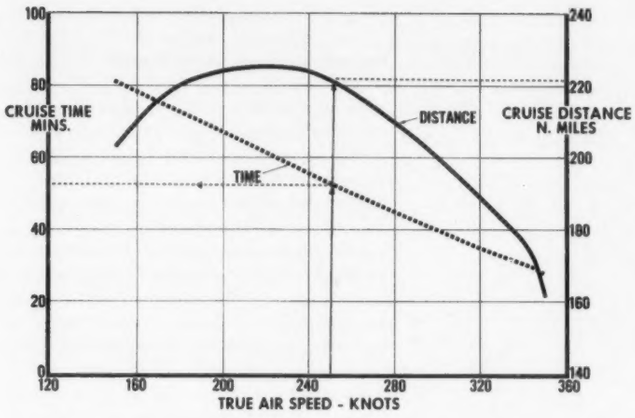
The CL-41 two-seat jet trainer built by Canadair Limited of Montreal, recently ordered for the Royal Canadian Air Force. A CL-41 was demonstrated for some weeks in various European countries, including Western Germany, Sweden, Holland, Belgium, and Switzerland.



A CL-41 has made a demonstration tour of various European countries. This lasted several weeks, Western Germany, Sweden, Holland, Belgium, and Switzerland being amongst the countries covered.

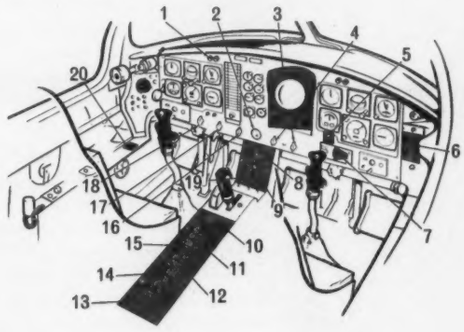
With the Lockheed F-104G supersonic fighter going into service with NATO units (as previously mentioned, Canadair is producing this aircraft under licence), the Canadian constructor is now also offering this two-seater jet trainer as a so-called Advanced Systems Trainer with the designation CL-41R; R stands for Radar, and this version is specially designed for the training of future F-104G pilots.

Basically, the CL-41R airframe does not differ from that of the CL-41 pure trainer version (see boxes and drawings), but it carries additional electronic equipment, which includes every item contained in the F-104G fighter, down to the last detail. Apart from the financial advantages (lower fuel consumption and price of about $ 500,000 comparing very favourably with two-seat versions of single-seat fighters) there is the matter of delivery; once the CL-41 is under series construction for the RCAF, delivery of the projected CL-41R could also be undertaken



The adjacent diagram, which refers to the CL-41R without external loads and at a relatively low flight altitude, shows cruise time in minutes versus true air speed in knots and, in addition, cruise distance in n.m., also versus cruise time in minutes. In other words, the diagram illustrates how a training flight can be planned in terms of desired air speed, radius of action, or flight time. Fuel reserves amount to five percent of maximum usable fuel. For 20 minutes loiter at sea level, an increase of five percent in the fuel flow must be allowed for.

Lay-out of the CL-41R cockpit (the extra equipment required for F-104 electronics installation is shaded). 1 – VHF channel indication lights; 2 – flap indicator; 3 – NASARR screen; 4 – internal and external lights; 5 – NASARR light controls; 6 – inertial navigator control; 7 – antenna tilt indicator; 8 – engine start; 9 – UHF manual tuning (incl. channel control); 10 – radar controls; 11 – intercom system; 12 – TACAN controls; 13 – circuit breakers; 14 – air conditioning controls; 15 – PHI controls; 16 – floodlights; 17 – instrument lights; 18 – console lights; 19 – SIF; 20 – UHF channel controls. The NASARR scope is facing the student in the right-hand seat for the elimination of parallax error and ease in reading.



Technical Data on the Canadair CL-41 . . .

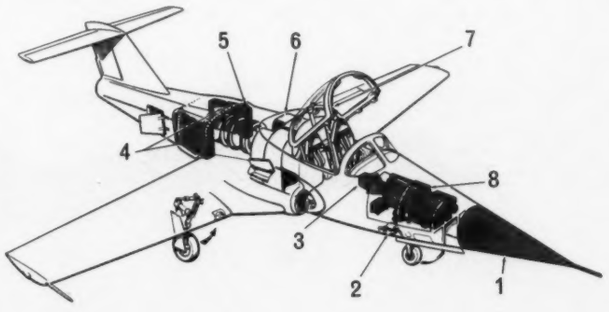
Wing span 36 ft 4 in; length 32 ft 0 in; wing surface 200 sq.ft; wing depth at root 8 ft 1 in, at tip 4 ft 0.5 in; height 9 ft 4.5 in; track 13 ft 2.74 in; wheel base 9 ft 5.25 in; span of horizontal tailplane 13 ft 7 in; take-off weight 7,200 lb; usable fuel 1,900 lb; maximum speed 387 kts (TAS) at sea level or 421 kts (TAS) at 30,000 ft; limiting Mach number 0.80; stalling speed 68 kts (TAS); rate of climb at sea level 3,650 f.p.m.; time to climb to 20,000 ft 7.2 min; service ceiling 44,600 ft; take-off distance to 50 ft at sea level (standard day, normal power): 2,230 ft; landing distance from 50 ft at sea level 1,570 ft. These data for the CL-41 are furnished by the manufacturers and comply with specification MIL-C-5911A. The CL-41 is powered by a Pratt & Whitney JT-12 (J60) turbojet engine, the thrust of which is, at present, quoted by the airframe manufacturers as 2,570 lb.

. . . and the Canadair CL-41R

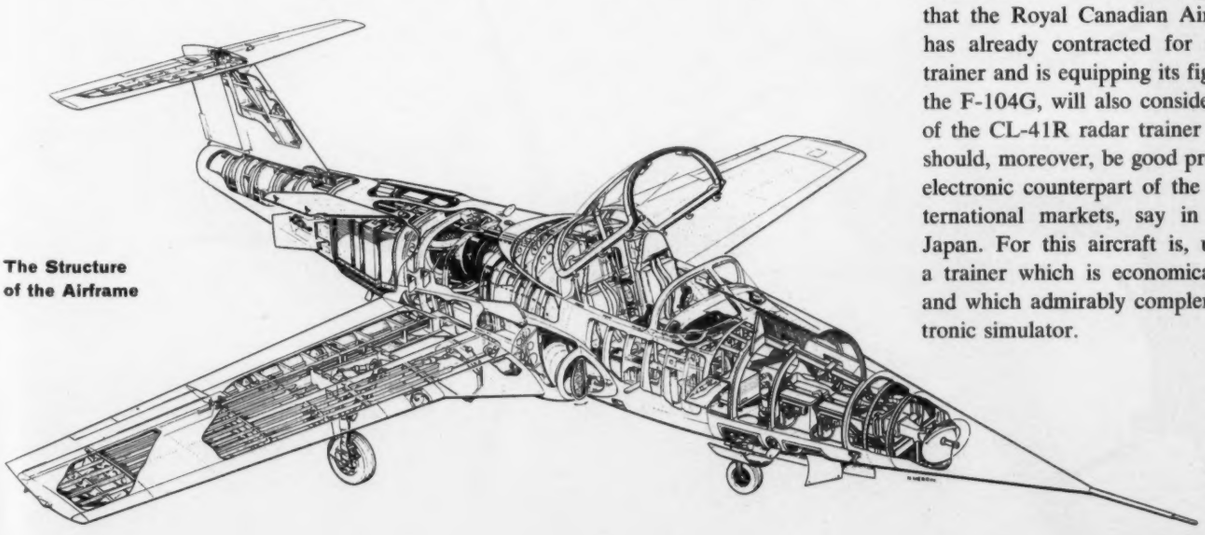
Principal measurements are indentical with those of the CL-41, save that fuselage length is 40 ft 7 in. The inclusion of electronic equipment as used in the F-104G has brought take-off weight up to 7,870 lb. In the CL-41R, a more powerful Pratt & Whitney engine, the JT-12A-6 with 3,000 lb take-off, 2,400 lb maximum continuous, and 2,140 lb maximum cruise thrust, constitutes the powerplant. Currently available details regarding flight performance are meagre. A maximum speed of 534 knots at an altitude of 20,000 ft is mentioned; rate of climb is 4,700 f.p.m., and time to climb to 20,000 ft is quoted as 6 min. As in the case of the CL-41, limiting Mach number will be 0.80.

The Equipment of the CL-41R

1 – Radome with R24A NASARR;
2 – Liquid oxygen converter;
3 – radarscope;
4 – F-104 "form factor" packages (including I/N computer, SIF, ADC computer, ARC 552, TACAN, NASARR low-voltage power supply, and NASARR electronic control amplifier);
5 – break point;
6 – fuel cells;
7 – pressurised cockpit with ejector seats;
8 – electrical bay (including inverters, voltage regulators, and inertial navigation platform). The additional F-104G electronic equipment installed in the CL-41R for training purposes is shaded on the drawing.



The Structure of the Airframe



within a relatively short time. The principal customers for the CL-41R would probably be those countries who have selected the F-104G as standard equipment for their fighter and fighter-bomber units.

As the drawings show, the CL-41R incorporates all the additional equipment necessary to make it completely equivalent, electronically speaking, to the F-104G. Like the latter, it is designed to carry electronic and radio components, such as the NASARR radar system; nose radome and pitot-static boom; inertial navigation system; TACAN; UHF communications system; selective identification feature; and air data computer.

It remains to be seen what headway the CL-41R radar trainer version of the CL-41 will make. It is, however, logical to suppose that the Royal Canadian Air Force, which has already contracted for the CL-41 jet trainer and is equipping its fighter units with the F-104G, will also consider the purchase of the CL-41R radar trainer version. There should, moreover, be good prospects for this electronic counterpart of the F-104G in international markets, say in countries like Japan. For this aircraft is, unquestionably, a trainer which is economical in operation and which admirably complements the electronic simulator. ◆◆

New Soviet Military Aircraft (2)

By the Interavia Study Group

In continuation of the series of articles commenced in *Interavia* 10/1961 (page 1434), on the subject of Soviet military aircraft and their armament, we here present five more, all of which were demonstrated at the Soviet Air Force's field day at Tushino this July. The five comprise two turbine-powered aircraft, one jet flying boat, and two VTOL transports.

The Tupolev Tu-16 medium bomber bearing the NATO code name *Badger* (silhouette H) has received a new radome, which carries an antenna of considerable dimensions. The glassing-in of the fuselage nose has been dropped, but the flattish radome below the cockpit (doubtless the same navigation equipment as hitherto) has remained. The large radar in the nose is certainly used to guide the missiles carried below the fuselage, which gives this already somewhat "dated" bomber new striking power. The missile, which is nearly 32 ft long, is similar to the North American GAM-77 *Hound Dog*. The latter is in fact somewhat longer—about 42 ft—but, in view of the more compact body of the Russian missile, it is unlikely to be heavier. The Russian missile's engine is situated beneath the body, and can be either a turbojet of very small diameter or a ramjet with additional rocket propulsion. A radome is also identifiable on the missile's fore-body, and it is to be supposed that this weapon is guided by a radar system that can be activated from the carrier aircraft. Based on the *Hound Dog's* performance, one would give this Soviet missile a range of some 625 miles. The *Badger* itself, with two Mikulin AM-3M turbojets, each of about 21,000 lb thrust, is reported to have a range of about 4,350 miles, without in-flight refuelling; its maximum speed can be estimated at nearly 600 m.p.h., and that of the missile at over Mach 1.5.

The turboprop bomber *Bear* (silhouette I) flown at Tushino differs in a similar fashion from its predecessor, in also having a radome in the nose and carrying a strategic missile about 52 ft long under the fuselage. The inclusion of the approximately 11-ft wide radome involved the complete reconfiguration of the fuselage nose. The unusual width of the radome is necessitated by an antenna of considerable size, which swivels sideways. As in the case of the *Badger*, this radar equipment probably serves for missile control into the vicinity of the target. The missile itself has highly swept wings and a swept tailplane—the surfaces could have been adopted directly from the Mikoyan supersonic fighter with the NATO code name *Faceplate*. Since the upper side of the guided missile is half-countersunk in the carrier aircraft's fuselage, it could nor be ascertained whether this weapon has an air inlet for a jet engine, in other words whether it is driven by a jet engine or a rocket motor; the relatively large diameter of the jet exhaust in the rear would rather suggest a turbojet engine. One can imagine that this missile—which also has a radar housing at its tip—is directed by the radar of the carrier aircraft for a considerable distance until it comes within reach of the objective, whereupon either automatic control or an automatic radar unit in the nose ensures that the target is reached. The range of the 180-ton carrier aircraft *Bear* is reported to be about 6,250 miles (without in-flight refuelling), and its cruising speed 470 to 530 m.p.h.

Much attention was given to the flying boat, with a fuselage about 100 feet long, shown at Tushino and attributed to the Soviet designer Beriev (silhouette J), which is undoubtedly designed for the same roles as the American Martin P6M *Seamaster* (meanwhile dropped).

The shape is, however, very different; the engines are beneath the wings and the horizontal tail plane is mounted high on the rudder assembly. A feature is the wide spray strip on the nose to prevent excessive penetration of salt water into the engines. Since, on the other hand, salt water intake can never be completely avoided with the

L—Twin-engined convertible aircraft by Kamov (NATO code name *Hoop*). This VTOL transport powered by two Ivchenkov turbine engines each of 4,000 h.p. has a large rear loading hatch and is reported to carry 60 to 80 troops or a corresponding load of vehicles.

Scale 1:400

K—Large crane helicopter by the Soviet designer Mikhail M. Mil. This model is a further development of the Mi-6 large helicopter by the same designer (NATO code name *Hook*) with two Soloviev TB-2BM turbine engines, each of 4,700 s.h.p. The two casings at each side of the centre fuselage are fuel tanks.

engine layout selected, it is assumed that the new flying boat is provided with engines resistant to seawater. The step below the centre fuselage is more pronounced than that of the *Seamaster*, and as in the case of earlier Western flying boat designs, is sharply tapered, which apparently increases seaworthiness. The wings have a marked anhedral, so that the outboard floats can be attached to the wing tips without long supports. In the rear of the flying boat's fuselage are housed a manned gun turret with twin cannon and a radar fire control unit. The fuselage has a glassed-in nose and could also accomodate a radome. The Beriev flying boat's engines are said to correspond basically to those of the *Badger* medium-weight bomber, which produces a total take-off thrust of about 44,000 lb. Since the flying boat is plainly smaller and lighter than the American *Seamaster* (which at 73 tons take-off weight produced a total thrust of over 50,700 lb), its take-off capacity in heavy seas should undergo a marked improvement, thanks to the shorter take-off distance.

The attention that the Soviet Air Force is giving to the problems of supplying the battle zone is clearly shown by the known existence of two new VTOL transports, for which there is no counterpart extant in the Western Air Forces. A crane helicopter has been derived from the well-known Mi-6 helicopter by the Russian designer Mikhail M-Mil (silhouette K). This recently carried a payload of 35,000 lb to an altitude of 7,250 ft. Powered (like the Mi-6) by two Soloviev TB-2BM turbine engines, each of 4,700 s.h.p., this helicopter has an enormous five-bladed rotor with a diameter of more than 115 ft, and a long-legged four-wheeled gantry-type undercarriage with strongly stiffened supporting legs. It differs further from the Mi-6 in that the fuselage has been altered and the cockpit provided with domed glass windows which allow the pilot to see backwards and downwards. The cylindrical, retractable housing beneath the nose is evidently for one observer or a second pilot who—having a good view backwards and downwards—supervises loading and unloading during hover. The helicopter could carry light tanks, armoured vehicles, and all types of special launchers, besides tactical ballistic missiles. There is, moreover, sufficient room for 50—60 fully-equipped troops.

A further new production on show in Tushino was a twin-engined convertible aircraft (silhouette L) with two propellers and two rotors, which are mounted at the end of a rigid wing. This convertible aircraft, designed by Kamov, bears the Russian designation *Vintokryl* (rotary-wing aircraft), and has been given the NATO code name *Hoop*. The *Vintokryl*, which is powered by two Ivchenkov turboshaft engines, each of about 4,000 s.h.p., distinguished itself at the Moscow display by its high cruising speed (over 205 m.p.h.) and unusually low noise level; this is of particular significance with regard to its use as a troop transport for surprise attacks in the battle zone.

H — Tupolev Tu-16 twin-jet medium-range bomber (NATO code name *Badger*) with strategic air-to-ground missile under the fuselage and large fire control radar in the nose.

I — Tupolev Tu-20 four-engined long-range turbo-prop bomber (NATO code name *Bear*), which also has a strategic air-to-ground missile under the fuselage and large radome in the nose. The projection above the radome could possibly be the retractable probe of an in-flight refuelling system.

J — Twin-jet flying boat by Beriev. Note the arrangement of the two jet engines under the wing and the spray strips at each side of the front fuselage in front of the engine inlets. A manned gun turret with a fire control radar above it can be seen in the rear fuselage; either a search radar or a glassed-in observation station is installed in the nose.

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I Fly the *Flex Wing*

By Lou Everett, Project Engineer, Ryan Aeronautical Company

There had never been an aircraft resembling it. In an era of missiles, rockets, space vehicles, supersonic fighters and bombers, this strange-appearing creation seemed incongruous. But when I sat on the *Flex Wing* platform for the first time, I experienced the sensation of initial discovery which must have gripped the Wright Brothers, Glenn Curtiss, and the other pioneers of flight.

This was Leonardo da Vinci brought up to date by Francis M. Rogallo, National Aeronautics and Space Administration scientist, whose flexible wing concept so intrigued Ryan that a test bed was designed by our Aerospace engineers and manufactured in the Company's main plant at Lindbergh Field, San Diego.

Rogallo had investigated the flexible wing's unique characteristics through wind tunnel and unmanned model studies and tests at NASA's Langley Research Center. Now came the full-scale flights with the research test bed. With no precedents to draw from, this arrow-shaped, kite-like object was to provide the data available only from manned flight.

The test bed of the *Flex Wing* utilizes such off-the-shelf items as a control wheel from a World War II bomber, a seat from an old light plane, and foot pedals from a more recent light plane. The wing is Mylar bonded to nylon. It hangs loosely between an aluminium longitudinal keel and two tubular leading edges flexibly joined, at the front end of the keel. The wing, with a span of approximately 40 feet, is like a boat sail in that its lifting power is derived from the flow of air which inflates it.

Suspended beneath the wing is the open-frame body with a four-wheel landing gear. A 180 h.p. Lycoming engine is mounted at the aft end of the fuselage, behind the pilot. The entire machine weighs about 1,500 pounds, including instrumentation.

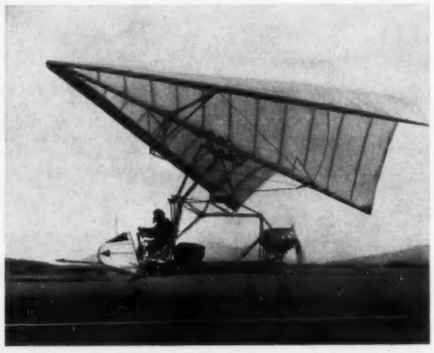
Among our first discoveries during the taxi runs was the need for relocating the wing pitch control pivot point. This is a critical feature, since the *Flex Wing's* control system functions without conventional hinged surfaces and flaps. The principle is the same as that used by the German glider pioneer, Otto Lilienthal, in the control of his gliders.

Lift and drag forces of the wing must pass through or close to the control pivot point in order to keep the control forces from being excessively high. Hence, proper location of the wing control pivot point as related to the wing itself is vital. The body of the *Flex Wing* swings from hinges between the pylon and the wing keel. I move the fuselage forward, backward, or sideward relative to the wing by manipulating the control yoke. This moves the horizontal position of the center of gravity relative to the center of pressure on the wing, causing moments which make the wing seek a new angle.

The first lift-off would answer many more questions. As I continued the taxi tests, these questions raced through my mind. Would the *Flex Wing* pitch up, roll over, "snake" back and forth, or just fly smoothly straight ahead?

Speeds are building up in taxi tests. That first lift-off could come at any time . . . ease back on the control column . . . it's getting light . . . we're airborne!

It responds nicely to pitch control, a little slowly, perhaps, but we expected that because this is characteristic of the delta wing at high angles of attack. My sensations are different from those experienced in any other flying machine. They can best be explained by imagining yourself sitting in a rocking chair controlled by a giant hand which occasionally rocks you sideways as well as back and forth.



The *Flex Wing* becoming airborne. The port wheels are on the point of leaving the ground, and the pilot can be seen applying corrective lateral control.

The author of the article explains details of the *Flex Wing's* controls to visiting Navy personnel.

The *Flex Wing* test bed is primarily a two-control vehicle, in that it has only pitch and roll control. Although lacking a rudder for conventional directional control, the plane has high directional stability. It has no tendency to sideslip; thus, when I bank, this stabilizing force keeps the nose coming around in a turn. For rising and descending, the wing is pitched relative to the platform by use of the conventional control column and wheel similar to that on most light planes.

There is no similarity with vertical velocity, as is associated with the attitude change in conventional aircraft. You feel an up and down motion integrated with forward velocity, similar to that in a helicopter, inasmuch as the test bed remains in a relatively level attitude. As for the rocking sensation, I quickly realized—and this was confirmed by motion pictures of the early flights—that this motion is confined to the platform, confirming the fact that the machine as a whole has strong stability.

As a result of our early flight tests, we have progressed through what can be considered a natural course of design changes and development. Most of the changes made were directly associated with proper location of the wing control pivot point as related to the wing itself.

It must be remembered that this test bed is not to be considered even as an experimental airplane. It is a research vehicle used to prove basic principles, which can be applied to a wide variety of missions of manned and unmanned vehicles that may be powered or unpowered. The applications of the *Flex Wing* range from small, powered reconnaissance drones, maneuvered by remote control, to huge, unpowered wings capable of recovering payloads and rocket boosters of 50 tons or more.

As our flight tests of the research vehicle for the US Army Transportation Research Command continue, we will be answering the big question:

Can a flexible-wing flying machine utilizing control by shifting the center of gravity be adequately controlled for all potential applications?

All indications to date point to an affirmative answer.

Inherent stability, extremely low storage volume, inexpensive light-weight construction, which allows more effective wing area per unit-weight than a conventional wing, greater lift for a given wing weight—these are qualities of the *Flex Wing* we are proving in the current test program. ⟷

Gold rush '61

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Unlike other automatic landing systems, the Bell ALS is ground-based, so a ground observer monitors every approach and landing. It can operate either fully automatically or under pilot control.

Military versions of the ALS have been ordered by the Air Force. The Navy has selected it for installation aboard the nuclear-powered aircraft carrier USS Enterprise as well as for its other large carriers.

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Guidance Systems for Air-to-Air Missiles

by T. W. J. Wong, Hughes Aircraft Company, Culver City, California, USA

An air-to-air guided missile usually includes among its major elements a tracking system, a control system, the airframe, electrical and hydraulic power supplies, and a propulsion system. An optimally designed weapon is produced by careful and systematic integration of these elements to achieve a missile with the desired performance characteristics. A discussion of the factors which influence the evaluation of a missile guidance system involves the consideration of all missile subsystems, but focuses attention on the control system and guidance equations.

The evaluation of guidance configurations requires the use of a measuring device or a set of performance criteria. These should include weapon system complexity (including reliability and maintainability), guidance accuracy, tactical or operational flexibility, and acceleration requirements. For reasons discussed subsequently, many operational guided missiles employ proportional navigation guidance systems. An examination of the major design parameters leads to a recognition of the trade-offs that must be made in configuring such a guidance system.

Information on target location is the most important single input to a missile guidance system. The form in which this information is provided serves as a basis for classifying the various guidance systems into the following categories:

1. Those based on prelaunch measurements only;
2. Those based on continuous interceptor measurements ;
3. Those based on continuous missile measurements ;
4. Hybrid systems, based on a combination of measurements.

In ballistic or inertial armament, target information available up to the moment of launch is used by the interceptor fire control system to aim the missile. Whether the rocket is fired forward or backward and whether or not a programmed turn capability exists, the missile trajectory is determined at launch by predicting the future position of the target and setting the missile autopilot so that the missile reaches this point at the same time as the target.

The errors which arise from making measurements at long range and assuming the right to linearly extrapolate prelaunch target position to impact position, limit the accuracy of an inertially guided missile. In the absence of target maneuvers, the miss due to system errors for a flight time of 4 seconds and a typical set of parameters is in excess of 100 feet. A 1 g target maneuver results in an average miss of approximately 200 feet, which is excessive for any conventional warhead of reasonable size. With longer flight times dispersion is much greater.

An inertially guided missile can be a very simple device. In its simplest form, it comprises only the airframe, a propulsion system, and some mechanism for obtaining flight stabilization, such as aerodynamic surfaces or spin induction. More complex forms include gyros or a platform reference and the actuators required for turning.

Design is generally directed toward maintaining high velocity and minimizing flight times and ballistic dispersion. Unfortunately, a high-precision fire control computer and complex ballistic mechanization are required within the interceptor, and great finesse is demanded of the pilot in steering the aircraft onto the appropriate lead course (either lead collision or lead pursuit).

The requirement for precise steering can be relaxed by adding a programmed turn capability within the missile. The turn program is set in accordance with the deviation of interceptor heading from the correct path. Such a procedure increases tactical flexibility and even permits rearward launching of missiles at targets behind the interceptor. Unfortunately, fire control system complexity is greater and the highly curved missile trajectory further increases ballistic dispersion. Rearward launching makes the problem of designing a stable missile more complex and introduces longer prediction times, thus increasing the magnitude of miss.

The lateral acceleration which the missile must be capable of generating depends on the type of missile. A purely ballistic missile needs no provisions for acceleration. The programmed-turn missile must be capable of accelerations proportional to the expected launch error and inversely proportional to its flight time.

While a ballistic missile itself is usually simple, the requirement for high fire control system accuracy makes tolerances critical and complicates maintenance procedures.

Because of the many drawbacks listed above, inertial reference is not always favourably received as a means of air-to-air missile guidance, despite its simplicity.

A second class of missile control includes those systems wherein fresh missile guidance signals are based on target position information received by the interceptor throughout the missile flight. Continual sensing of target position minimizes the deleterious effect of target maneuvers on accuracy. Furthermore, later measurements are made at reduced interceptor-to-target ranges where the magnitude of sensing errors is reduced. Thus, a higher degree of guidance precision exists than that achieved with an inertial system. Examples of guidance systems which fall into this category include the line-of-sight beam rider and command-guidance systems.

The line-of-sight beam rider derives its guidance from a constraint to remain in the center of the interceptor radar beam, which is pointed at the target. The equipment required to sense the displacement of the missile and provide the required corrective acceleration is moderately complex in nature. There must be a receiver to sense energy transmitted by the interceptor's radar and some form of roll reference or stabilization in the missile to establish the direction of missile displacement, as well as provisions for receiver signal processing, basic error-signal computation, and trajectory damping. Interceptor equipment requirements range from very minor to relatively complex, depending on the method of missile capture in the radar beam and the type of interceptor trajectory.

The accuracy which is obtainable from a beam-rider system depends on two major factors: ability of the interceptor radar to track the target accurately, and the ability of the missile to remain centered in the interceptor radar beam. Except in the presence of jamming or chaff (window), interceptor radar tracking of the target should be of sufficient accuracy so that it will not be the dominant source of error.

The ability of the missile to remain centered in the beam depends on several factors: a kinematic error arises from any rotation of the interceptor-to-target line of sight because of lags in missile response. The nature of the missile's error-sensing and control system is very important, for it determines the amount of miss in the presence of such disturbing effects as the capture transient, random disturbances, and line-of-sight rotation.

In order to reduce the effects of the capture transient and line-of-sight rotation in the terminal portion of missile flight, while keeping equipments minimal, compromises in the tactical employment of the missile are required. If the missile is launched on a pursuit course, it is most easily captured in the radar beam. However, this results in a rotating line-of-sight and requires continuous missile acceleration except in attacks at the target nose and tail aspects. The ability of the missile to remain in the center of the radar beam is decreased in such a dynamic situation and, unless a sophisticated control system is employed, the miss increases to the point where kill effectiveness is likely to be seriously degraded. Line-of-sight rotation and resultant missile acceleration is reduced if the interceptor converts from a pursuit course to a target collision course immediately after launch. Unfortunately, the interceptor turn may require 10 seconds or more, and excessively long missile launch ranges are necessary to assure a non-accelerating phase of reasonable duration.

A nonrotating line-of-sight between interceptor and target exists from the start if the missile is launched from an interceptor-target collision course. However, the lead-angle required at launch causes the missile to fly away from the line-of-sight and introduces the need for a mechanism to direct the missile into the interceptor radar beam. Because capture of the missile in the radar beam is accomplished at short range, it is feasible to employ an auxiliary antenna which is originally oriented straight ahead along the initial missile flight path and subsequently brought into coincidence with the primary track-

ing radar. Alternatively, it is possible to include in the missile a programmed turn which will bring it into the interceptor radar beam. While employment of devices such as these simplifies the interceptor tactic into one of remaining on a collision course, it does require additional equipment either in the fire control system or in the missile.

Launching from a collision course does simplify interceptor operations, but additional time is required to effect missile capture. It is possible to compromise between this procedure and the pursuit launch procedure, wherein immediate capture can be achieved at the price of tactical complexity. If the interceptor launches the missile from between a pursuit and collision course, both the missile and interceptor can maneuver, and the time required to effect capture of the missile in a nonrotating radar beam is minimized.

The lateral acceleration capability required of the missile varies greatly with the operational procedure employed. If the interceptor launches on a pursuit course and continues on that course, accelerations of 10 g's or more are possible at the termination of the flight. When the missile is captured in a nonrotating line-of-sight, acceleration requirements are small, only large enough to compensate for random disturbances, missile slowdown, and target acceleration. However, attaining this steady-state condition in a reasonable length of time necessitates large missile acceleration in the capture phase. A 10- or 15-g capability is not considered excessive. The missile acceleration required in the presence of target maneuver is nominally small but is increased by launch errors. When the missile is captured in a nonrotating line-of-sight, it is on a collision course with the target, and accelerations due to target maneuvers will not exceed the magnitude of target acceleration.

The command-guided missile, which belongs to the same class of guidance system, also receives its direction from the interceptor fire control system. Rather than derive error signals from the tracking radar beam, it receives command signals through a communication link. This system generally reduces the amount of equipment required within the missile, but requires additional hardware in the interceptor. Again, a reference system must be included in the missile so that appropriate directional sense is assigned to the received command. While the radar receiver and associated processing equipment can be eliminated in one configuration, the missile must then carry a UHF, VHF, or other communication receiver.

To generate the desired steering signal, position and velocity of the missile as well as the target must be available in the system. The possible command guidance systems differ only in the manner in which the interceptor obtains this information. Among the alternatives possible are inertial instrumentation of the missile, dead reckoning of the missile position based on past commands, and tracking of the missile. The first method has the drawback of requiring an additional data link between the missile and interceptor. The second method is not only inaccurate, but also requires a complex computing system in the interceptor. The system which involves tracking of the missile as well as the target appears to be most satisfactory and hence will be considered further.

The interceptor tracking radar can be employed to track the target as well as the missile. In fact, it can be made to generate the required missile error command and produce a command-guided beam rider which is similar to the beam rider except for the fact that error is measured at the interceptor rather than at the missile. Through the employment of a single tracking system, alignment errors are eliminated, and the potential for an accurate command guidance system increased. While this system does not possess the accuracy of the beam rider, it does impose all the beam capture and tactical complications of the beam rider.

A second radar beam can be introduced to guide the missile and eliminate the need for a data link. In such a system, orientation of the auxiliary beam is based on a program calling for coincidence with the target tracking beam just at impact. The beam is initially pointed straight ahead to capture the missile at launch. The missile must maneuver to achieve a collision course with the target, so that the auxiliary beam is rotated at a rate compatible with the lateral acceleration capability of the missile. Subsequently, the rate of rotation of the missile beam is based on kinematic equations similar to those that govern the flight of a ballistic rocket.

Once again there is the possibility of trade-offs between complexity of the weapon system and of tactical procedure. The single-beam command guidance system is operationally similar to the beam-rider system discussed earlier, and the same conclusions on beam capture and terminal dynamic miss phenomena are applicable. The dual-beam command system is committed to a complex missile and fire control system configuration, but provides the least encumbered operational procedure.

The single-beam command guidance system offers the potential of a high degree of guidance accuracy, limited only by the ability of the interceptor radar to resolve between the missile and the target. In contrast, the two-beam system introduces errors through misalignment of the two beams and misprogramming orientation of the second beam; therefore its maintenance is a formidable task.

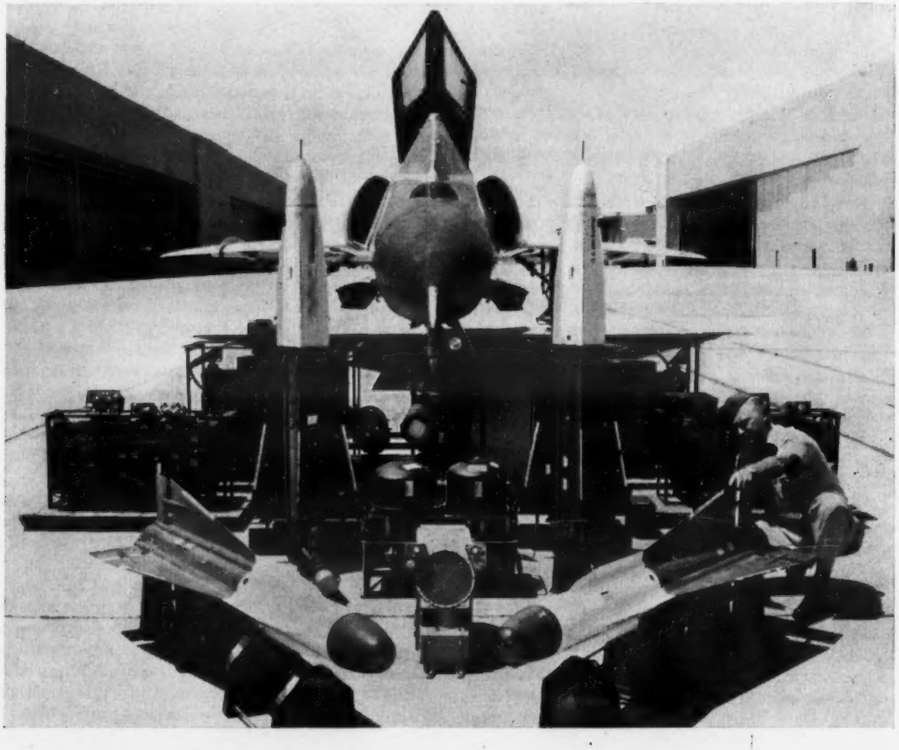
Since the single-beam and dual-beam command guidance systems both produce missile trajectories similar to beam-rider trajectories, their lateral acceleration requirements are also similar. A minimum acceleration capability of 10 or 15 g's should therefore be available to ensure acceptable capture characteristics at all operational altitudes. Acceleration required in the presence of target maneuvers is reasonably small.

In a third class of guidance systems, called homing systems, are missiles which generate their own error signals on the basis of measurements made by the missile itself. The effect of target acceleration is minimized by virtue of continual measurements taken during the missile flight. The highest degree of guidance precision is also possible because of the missile's close proximity to the target when the final measurements are made.

A continuous measure of target angular position is sufficient to provide the required missile guidance. Several different forms of homing guidance are possible when using target angular position measurements. In pure pursuit steering, the missile maneuvers to bring its velocity vector into correspondence with the direction to the target. While requiring the smallest amount of equipment, this form of steering results in a continuously curved trajectory and an attendant lateral acceleration requirement for all attacks except those on the target nose and tail. In some geometric and velocity situations, the ideal trajectory produces the requirement for infinite terminal acceleration, consequently a miss results from normal acceleration limits. While producing a different path, fixed lead-angle steering results in hardware requirements and trajectories similar to those of the pursuit system. By turning in such a manner that the line-of-sight from the missile to target maintains a constant direction in space, the missile achieves a constant bearing course. Except for variations in missile velocity, a straight-line path to collision with the target results. Because error signals are proportional to rate of rotation of the line-of-sight, the system is designated as " proportional navigation."

In order to obtain the necessary measurement of target location, a tracking system must be incorporated in the missile. A signal processing system is required for generation of steering signals from tracking information and an antenna gimbal system and provisions for antenna posi-

About 200 components go to make up the complete Hughes MA-1 fire control system, which is now to equip the USAF Convair F-106 fighter interceptor (pictured here), the Convair F-102A, and the McDonnell F-101B. This fire control system is suitable for the Hughes *Falcon* air-to-air guided missile with radar homing head (shown vertically) and infrared homing head (shown horizontally).



Optimization of Proportional Navigation — Homing Missile Parameters

Homing missiles which employ proportional navigation as a means for achieving a collision course with the target have been received with considerable favor. Some practical performance factors affecting choice of values for essential parameters (navigation gain and smoothing time constant) of such a missile are given in this section.

Examination of a perfect proportional navigation system (i.e., one with no lags) shows the dependency of missile acceleration in the presence of launch error and target acceleration on the navigation constant.

The proportion navigational guidance equation can be written as follows:

$$\dot{\gamma} = \lambda (\dot{\sigma} + \dot{\eta}) \tag{1}$$

where γ is the flight-path angle of the missile

λ is the navigation constant

σ is the angular position of missile line-of-sight to the target with respect to some fixed reference and

$\dot{\eta}$ represents any of several possible errors in the system.

Note the usual kinematic equations that apply to a two-body (missile and target) system.

$$R\dot{\sigma} = V_T \sin(\Phi - \sigma) - V_M \sin(\gamma - \sigma) \tag{2}$$

$$\dot{R} = V_T \cos(\Phi - \sigma) - V_M \cos(\gamma - \sigma) \tag{3}$$

where R is the range between missile and target

V_T is target velocity

V_M is missile velocity and

Φ is the target heading (relative to the same reference as σ and γ).

Assuming that the target and missile velocities are constant, these kinematic equations can be combined to yield

$$\ddot{\sigma} = -2\frac{\dot{\sigma}\dot{R}}{R} + \frac{V_{MR}}{R}\dot{\gamma} + \frac{a_{TP}}{R} \tag{4}$$

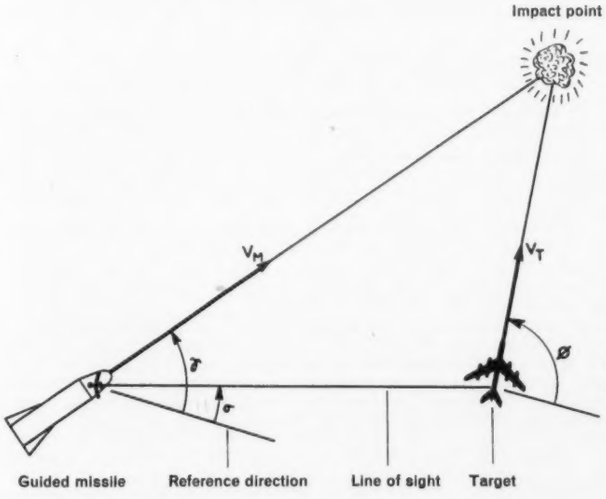


Fig. 1: Ideal attack geometry for the target approach of an air-to-air missile V_M — missile speed; V_T — target velocity; angles γ, σ, and φ are explained in the text.

where $V_{MR} = V_M \cos(\gamma - \sigma)$ is the component of missile velocity along the line-of-sight and a_{TP} is the component of target acceleration normal to the line of sight. This equation can be combined with the proportional navigation guidance equation to produce a first order differential equation in $\dot{\sigma}$. Assuming that $\dot{R}$ and V_{MR} are constant and $\dot{\eta}$ is zero, the trajectory solution of the differential equation can be readily obtained by integration.

$$\lambda\dot{\sigma} = \dot{\gamma} = \lambda\dot{\sigma}_o \left(\frac{R}{R_o}\right)^{\Lambda - 2} + \frac{\Lambda}{\Lambda - 2}\left[1 - \left(\frac{R}{R_o}\right)^{\Lambda - 2}\right]\left(\frac{a_{TP}}{V_{MR}}\right) \tag{5}$$

where Λ is the *effective navigation constant* $\left(\lambda \cdot \frac{1}{r}\right)$ and $\left(r = \frac{-\dot{R}}{V_{MR}}\right)$.

Further discussions will center around the effective navigation constant, Λ, for it possesses more unique characteristics than the navigation constant itself.

The manner in which the effective navigation constant, Λ, affects the decay of the initial launch error and consequently the commanded acceleration, is shown in *fig. 2*, which is plotted from the first term of the trajectory solution (5). It is seen that for a Λ of 2, the interceptor acceleration does not vary, and the initial error persists through the flight. Lower effective navigation constants result in divergent acceleration and miss. A navigation constant of 3 or 4 results in acceptable acceleration and miss decay rates.

The second term of the trajectory solution is used to plot *fig. 3*, which shows the effect of different effective navigation constant values on the rate of decay of missile acceleration required in the presence of steady target acceleration. It is seen that a Λ of 2 results in the requirement for infinitely large missile acceleration at the end of flight. A navigation gain of 3 produces more acceptable acceleration requirements. Increasing the value to 4 reduces the terminal acceleration requirement by 35 percent, but increasing it to 5 only results in an additional 15 percent reduction.

From *figs. 2* and *3* it would seem that the value Λ should be as high as possible. However, compatibility with noise and stability requirements arising from feedback mechanisms in the missile system necessitate a compromise. To minimize the terminal missile acceleration and miss in the presence of continuous target acceleration, the highest value of Λ is desired, as shown in curve A in *fig. 4* which is directly derived from *fig. 3*. Curve B, however, shows that increases in Λ result in increased response to spurious measurements such as radome error and noise, and a consequent increase in miss. No numerical significance should be attached to this noise curve, for specific values of acceleration depend on the noise power density and filtering system. The presence of a relative minimum in the total acceleration curve indicates that an optimum value of navigation gain does exist. While the exact

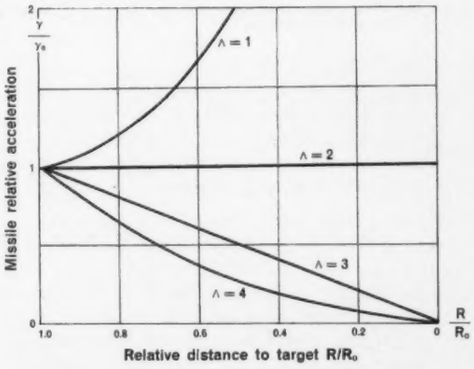


Fig. 2: Effect of the effective navigation constants Λ on the relative missile acceleration required for the compensation of initial launch error (trajectory angle). Target velocity is constant. For further explanation, see text.

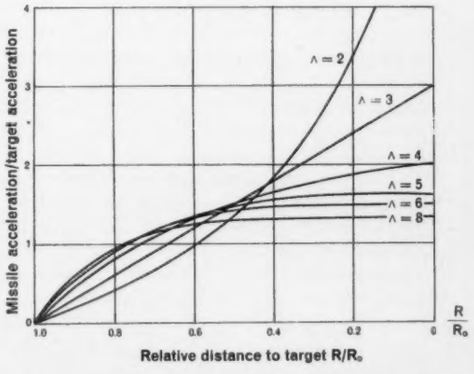


Fig. 3: Effect of the effective navigation constants Λ on the missile acceleration resulting from steady target acceleration.

tioning are necessary if steering other than of a pursuit course is employed. Such missile subsystems generally require maintenance attention to radar-processing circuitry, if the tracking system is of that type, and to the gyroscopes employed to sense target line-of-sight rotation rate.

Constant-bearing homing guidance is capable of providing the highest degree of guidance accuracy because of the proximity of measurements and because there is no acceleration required in the steady-state terminal phase. Thus, as the missile makes angular rate measurements in its approach to the target, only the acceleration required for corrective maneuver exists. Target maneuvers result in nominal missile acceleration which never exceeds the magnitude of target acceleration. A capability for large lateral acceleration is required only if large launch errors are expected.

Homing missiles provide a high degree of tactical feasibility. The requirement for radar illumination of the target in the case of a semi-active missile requires that the interceptor continue tracking the target during missile flight. For a nominal flight time (i.e., less than 10 or 15 seconds) any interceptor escape maneuver is acceptable. When missile tracking-system sensitivity is such that inadequate tracking range exists at some target aspects, the weapon system is restricted to conducting attacks over limited aspect angles. For example, missiles which employ infrared tracking are frequently limited to tail attacks. Because of the exceedingly large steering transient that would otherwise exist at launch, a missile that employs proportional navigation and

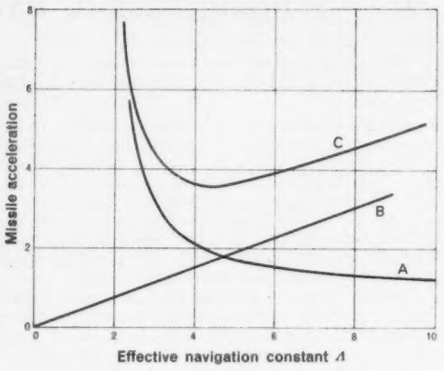


Fig. 4: Diagram for the selection of the optimum Λ value. *Curve A* shows the required terminal missile acceleration expressed as a multiple of target acceleration, assumed constant. *Curve B* represents the effect of noise in the navigation system. The total acceleration *curve C* generally has a minimum point which shows the optimum value for Λ.

location of the minimum depends on the character of the system noise, target acceleration effects are dominant at a low Λ, and it is clear that values near 2 are not tolerable. Stability considerations give rise to a curve similar to the noise curve of *fig. 4*. This factor must be considered in like manner when optimizing system gain.

The choice of a dominant smoothing time constant involves a compromise between conflicting requirements for minimized miss. The solid curves of *fig. 5a* show that increased smoothing time results in a larger portion of initial launch error existing at the end of flight. This fact is most pronounced for short flight times and least pronounced for long flight times. The dotted curve of *fig. 5a* shows that miss due to noise has the opposite behaviour, decreasing with increased smoothing time. The noise miss is essentially independent of flight time, and it increases very rapidly when smoothing time diminishes to such a small value that required random acceleration exceeds the missile capability. A root mean square sum of miss distances arising from the two effects is shown in *fig. 5b*. It is immediately obvious that an optimum filtering time exists for finite missile flight times. Further, longer flight times result in lower miss distances when the smoothing time is increased appropriately.

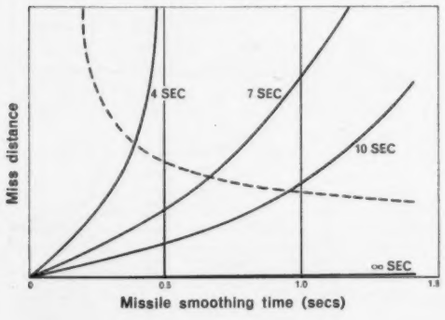


Fig. 5a: Average miss distance as a function of missile smoothing time. The extended curves show the effect of the launch error (parameter is total flying time), whilst the broken curve illustrates the error caused by noise.

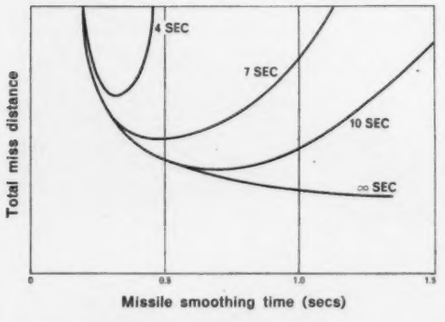


Fig. 5b: This records total miss distance, i.e. sum of the individual errors shown in *Fig. 5a*. In the case of finite total flight time, there is at any point a minimum, which gives the most favorable smoothing time.

Implementation to Achieve Desired Parameters

Having determined optimum values for navigation gain and smoothing time, there are several means by which these parameters can be implemented in the missile. Consider the block diagram of the missile system shown in *fig. 6*. Using the definition of effective navigation constant and the d-c gain of *fig. 6*,

$$\Lambda = \lambda \cdot \frac{1}{r} = \frac{\dot{\gamma}}{\dot{\sigma}} \cdot \frac{1}{r}$$

$$\Lambda = \frac{K_{20}\, K_{40}}{K_2\, \rho_0\, a_0} \cdot \left(G_r\, G_\rho\right) \cdot \left(\frac{\rho a}{r}\right) \qquad (6)$$

The first factor in this equation is a constant that can be adjusted to provide the desired value of effective navigation constant. The third factor varies with altitude and the kinematics of the attack. Compensation for the undesirable variation of this factor is accomplished through programming (based on altitude and range rate) the gain terms of the second factor, G_r and $G\rho$.

The equivalent of two filters exists in *fig. 6*. Z(p) represents the aerodynamic response of the missile, including rate feedback or stabilizing networks. The effective aerodynamic time constant is usually small compared to the major smoothing time constant which is introduced and controlled at the missile seeker. The closed loop around the seeker gyro produces the following transfer function,

$$\frac{1}{K_1} \cdot \frac{p}{\frac{1}{K_1 K_2}\, p + 1} \qquad (7)$$

Thus the major filtering time constant, τ_a, can be controlled by the gain, K_1.

$$\tau_a = \frac{1}{K_1 K_2}$$

Several other forms of control system exist. The introduction of accelerometer feedback can be made to eliminate the variation of gain with altitude. The use of the torque balance system produces the same result if a specific type of control surface effectiveness can be achieved. Unfortunately, both systems eliminate the need for altitude compensation, which is readily achieved, while retaining the need for kinematic compensation, which depends on interceptor radar measurements. However, consider the value of the kinematic term of the navigation constant equation in tail aspect attacks.

$$r = \frac{-\dot{R}}{V_{MR}} \cong \frac{V_M - V_T}{V_M} = 1 - \frac{V_T}{V_M} \qquad (8)$$

Since the ratio of target velocity to missile velocity is kept at a relatively small fraction of unity when boost velocity is high, the use of typical values for V_T and V_M will not introduce significant errors in a preselected value of r if only tail aspect attacks are considered. In this situation, the geometry parameter, G_r, can be eliminated. Complexity of the control system can thus be reduced, but at the cost of reduced tactical effectiveness.

Many factors must be evaluated before the best guidance control system for a particular application can be selected. The system described in *fig. 6* is simple and is conducive to the construction of a small missile. However, such a missile is dependent upon the radar, an air data system, and the ability of a fire control system to compute the necessary gain compensation.

The use of accelerometer feedback introduces additional hardware and complicates missile stability design. However, it makes it unnecessary for the fire control system to provide altitude-dependent gain compensation. The torque balance system also eliminates the need for this gain compensation, but at the price of requiring special aerodynamic characteristics. The difficulties encountered in the art of aerodynamic design frequently result in discarding this approach.

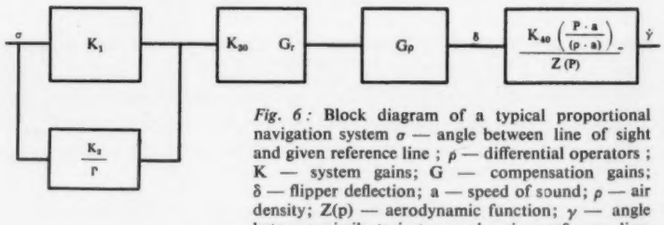


Fig. 6: Block diagram of a typical proportional navigation system σ — angle between line of sight and given reference line ; ρ — differential operators ; K — system gains; G — compensation gains; δ — flipper deflection; a — speed of sound; ρ — air density; Z(p) — aerodynamic function; γ — angle between missile trajectory and a given reference line.

cannot track a target at large lead angles is also limited to tail aspect attacks.

A fourth class of missile guidance systems is generated by combining several of the previously discussed techniques. Hybrid guidance systems offer the ability to meet performance and tactical specifications that would be difficult to achieve otherwise, but pay the price in terms of increased size and complexity and an attendant reduction in reliability. Many criteria are used in combining guidance systems, but matching to complement operational and performance features is the first essential. In this manner, the deficiencies of one guidance system can be overcome by the virtues of another. For example, the larger miss distances that characterize inertially or command-guided missiles can be reduced by employing homing or line-of-sight beam-rider guidance in the terminal flight phase. In the same way, the difficulty the homing missile encounters in tracking at extremely long launch ranges can be eliminated.

As has been inferred in the foregoing paragraphs, it is difficult to assign quantitatively a performance level to each type of missile guidance. Specific data regarding missile aerodynamics, control system parameters, warhead, fuzing system, and interceptor fire control system characteristics, would be required. However, an attempt has been made to examine and compare in a qualitative manner some of the key elements and characteristics of each system. The best choice for any particular missile to a great extent depends on the target threat which the missile must meet, the fire control system with which it is employed, and the operational environment in which it is used. ◆◆

Two Opposite Roles

Whilst the preceding article dealt with the various control systems of air-to-air missiles, the contributions which follow describe examples of air-to-ground and ground-to-air guided missiles. Whatever the differences in aerodynamic configuration and control system, practically all guided missiles have one common factor, namely that both the body and the electronic equipment must be carefully coordinated from the outset and merged into one inseparable whole. The design parameters are numerous—engine thrust, control surface factors, destructive power of the warhead, accuracy of the target homing device, and control system reaction time, to mention only some—and the task of finding the optimum solution, with which the designer is faced, is an extremely complex one. A further difficulty is that, from an early stage, allowance must be made for possible later improvements in one or more of the integral sub-systems.

When design offices all over the world went over to guided missiles to be launched from mobile platforms against fixed targets, they relied to a large extent on existing experience obtained from air-to-air missiles. For interception purposes, it is a matter of missiles which can, in flight at high altitude, be launched at twice the speed of sound and can be guided either visually or, more commonly, by airborne radar. The aircraft from which the missile was launched spotted, so to speak, the enemy in flight. Its computer ascertained the enemy aircraft's flight path, whereupon the radar first saw to it that the air-to-air missile was launched at the most favourable instant and then guided it into the immediate vicinity of the target. The necessary guidance was achieved in one of two ways, either by the emission of electromagnetic waves which, when reflected by the enemy aircraft, "attracted" the missile's homing head, or by pre-setting the flight path along which the missile would presumably hit its target.

Since the engines in modern aircraft develop considerable heat-radiation, a sensitive infra-red sensor can, of course, be used to "show the missile the way." This self-homing control system offers the further advantages of being relatively insensitive to enemy jamming and of not requiring any complicated equipment in the carrier aircraft. On the other hand, it is ineffective in bad weather, when the infra-red radiation is absorbed and destroyed by water vapour.

Similar methods—with the obvious exception of the infra-red system—have also been used as a basis for air-to-ground weapons. A number of such weapons have been designed with radio command guidance systems, in which the pilot's function is to guide his weapon by means of a small switch or control stick, in such a way that target and missile lie constantly on one straight line. For tactical missions and in attacking fixed targets in the battle area, this method gives acceptable results when visibility is good or medium and at ground speeds of 500-600 kts. For rockets of this type, miss distance should not normally exceed some 40 ft.

In general outline, the operation proceeds as follows. The pilot, flying at low level, approaches the zone in which he supposes the objective to lie. According to the size and visibility of the target, he flies past it in an offset position and then, still in low-level flight, curves round to bring his aircraft into the firing position. He can then climb, fire his rockets from a distance of 4 to 7 miles, and guide them visually on to the target. The arrangement of the control surfaces and the speed of the missiles allow accelerations between 2 and 4 g, which means that, in his approach flight towards the target, the pilot has some room in which to manoeuvre.

One could, properly, assume that an attack of this type would be considerably simplified by using distance measuring equipment throughout the operation. In fact, experience has shown that, even at ground speeds of Mach 0.7-0.8, only relatively small distance errors arise which are, in any case, partly offset by the sighting methods. The aircraft must naturally retain some possibility of manoeuvre during the remote control phase, and the pilot must accordingly be provided with a reference system independent of the roll of his aircraft. Designers are now looking for means of eliminating the need for pre-launch reconnaissance, so that the target can be sighted directly from a minimum altitude. This would allow the aircraft to make the fullest use of the cover offered by the terrain.

Provided the pilot is briefed on the geographical details of the battle area and acquainted with the coordinates of the target, he can, using an inertially guided missile, pre-calculate the point at which he will launch it. This point would be selected for easy identification, with reference to altitude and speed of flight and to probable weather conditions. The pilot then steers his aircraft at near-ground level towards the easily identifiable launch point and, on reaching it, fires his guided missile. He then alters course and maintains a considerable lateral distance from the target.

It is hoped that high performance radar and weapon guidance equipment will make it possible to launch rockets in this way even in very unfavourable atmospheric conditions. Attacks of this type are, of course, possible only when the objectives are static, and for this purpose the low-level attack aircraft, armed with air-to-ground missiles, will come up against serious competition from the high-precision ground-to-ground ballistic missile.

In the case of the ground-to-air weapon, conditions are, to some extent, reversed. Whereas the air-to-ground rocket is launched from a fast-moving platform against a fixed target, or against a vehicle which is moving very slowly as compared with the carrier aircraft, the anti-aircraft missile starts from a stationary launching ramp and is required to hit a very rapidly moving and elusive target. Another factor is that, despite the most modern early warning systems, an anti-aircraft unit located close to the front sometimes cannot be alerted until the last moment, whereas a low-level attack aircraft usually has the element of surprise on its side.

There are, in general, greater demands on the ground-to-air weapon in respect of manoeuvrability and engine performance. In the case of weapons carried by aircraft, on the other hand, every pound of weight and cubic inch of space has to be considered. The carrier aircraft's measurements and flight performance forced the air-to-ground missile designers to think from the outset in terms of miniaturisation, as applied both to the missiles and to the corresponding electronics on board the aircraft. Ground-based weapons systems could, however, be larger and heavier, with a resultant gain in range and precision. Meanwhile, the demands of the military strategists for maximum mobility in ground-based missiles gave rise to trends which are likely to leave their stamp on developments in this field for the time being, namely: systematic weight reduction; simplification of maintenance; transition to small, independently operating units.

The weight of the guided missiles themselves is basically determined by their "payload," in other words by the destructive power required in the warheads. What further progress can be made with chemical explosives remains to be seen. In the unanimous opinion of the experts, atomic warheads can still be considerably reduced in size, while nevertheless retaining their destructive power. Quite apart from objections in principle, atomic weapons cannot be used in many tactical operations, if only for the sake of the safety of the user's own forces. Thus, the only course open remains consistent miniaturisation of the control system. However, in view of the ever-increasing speed of aircraft—bombers are already flying at Mach 2.0 and over, not to mention the supersonic aircraft for low-level attack which are currently being developed—such miniaturisation must not be achieved at the expense of precision and reliability. In other words—and this is true not only of the guided missile—the future of many such projects depends more than ever on advances in the field of electronics. ←

Bullpup –

A Douglas A4D *Skyhawk* single-seat naval combat aircraft, armed with two *Bullpup* rockets and carrying a large extra fuel tank.

A Versatile Command-Guided Air-to-Ground Missile

In future, the main task of the tactical air forces, namely to cripple enemy potential in the battle area, or immediately behind it, will inevitably fall either to the ballistic rocket or alternatively to the low-flying aircraft, the latter armed with guided missiles (controlled automatically or by the pilot) for launch at some distance from the target. The aircraft in question would remain out of range of the enemy's close defences and change course as soon as possible, i.e. before the missile has reached the ground. This method of attack is also effective for engaging and destroying sudden, opportunity targets. In either case, the pilot utilises his guided missile to direct the warhead on to the objective with the maximum of accuracy and the minimum of danger for himself and his aircraft. Any Korean war pilot who, in order to drop his bombs on to his target, was forced to fly his aircraft at heavily defended enemy positions, will need no convincing of the advantages of the guided missile over dive and toss bombing.

In order to give itself the opportunity of testing this method in practice and of perfecting it, the US Navy asked the Martin Company to develop a suitable missile which the pilot could guide on to the target by radio command and which – rather like a "flying bomb" – was to be inexpensive in production and simple to use.

This gave birth to the missile christened *Bullpup*, whose design takes into account all the experience gained in the Korean war. *Bullpup* is, as it were, the long arm of the pilot, who no longer needs to fly his machine "down the enemy gun barrels," but can instead achieve the desired result by using remote control push-button radio signals, provided only that visibility is adequate.

From the very start, the planning chiefs of the Bureau of Naval Weapons, the Department responsible for *Bullpup's* development, were adamant on one point, namely that the weapon and its guidance system had to be accurate enough to hit at several miles' distance targets such as enemy warships, concentrations of armour, railway junctions, or fortified defence positions, with the maximum precision not inferior to that the human eye can attain. It had also to be so designed as to eliminate the need for complicated electronic checkout testing or other time-consuming preflight preparations. The weapon in its final form is, in fact, delivered by Martin in three sections, which can be assembled and mounted on the carrier aircraft by three men in the space of a few minutes.

•

What does the Martin missile look like? Its exterior configuration can be seen from the illustrations to this article. The wing configuration chosen, and the guidance fins on the forebody, ensure immediate and accurate reactions at speeds up to about Mach 2. Since the heavy explosive charge is contained in the centre section, the inertial moments about the yaw and pitch axes are reduced, thus enhancing *Bullpup's* manœuvrability. In the interest of maximum flexibility, the central warhead section has been made interchangeable. In other words, using the same nose section (which contains the guidance receiver and other guidance equipment) the warheads may be varied in accordance with mission.

The three main parts of the weapon are:

1 – The tapering nose cone, housing the receiver for the pilot's guidance commands, amplifiers, control valves, and a pneumatic servo-system for actuating the delta fins;

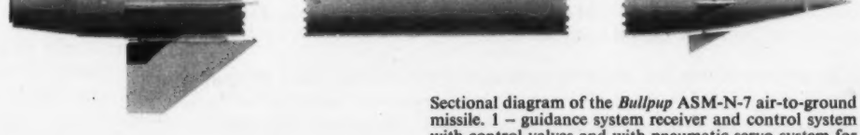
2 – the cylindrical centre section, containing the interchangeable warhead (weight about 250 lb), the fuse, and the arming device;

3 – the aft section, comprising a booster rocket motor which accelerates the missile up to speeds approaching Mach 2. There are two alternative means of propulsion: a solid-propellant motor developed by the US Navy or a Thiokol rocket engine with storable liquid propellants. Four cruciform delta wings are mounted on attachment points on the circumference of this section, and these give the required lift. The aft section also carries two tracer flares, which assist the pilot in tracking the missile over long distances.

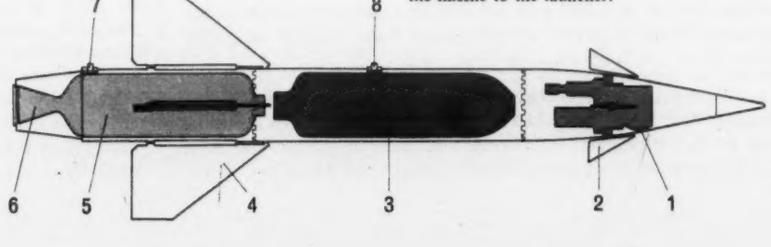
Other elements of the *Bullpup* system are:

- launchers, which are as a rule fixed to pylons under the fuselage or the wings of the carrier aircraft;
- a signal transmitter inside the aircraft;
- a transmitting antenna, customarily installed on the door of the nose wheel bay;
- a special thumb switch, located on the pilot's

Once its three component sections are mated (a matter of seconds), *Bullpup* is fully operational. The sections are *(right to left)*: 1 – the nose section, accommodating the receiver for the pilot's guidance commands, the guidance system, the control package, and the guidance fins; 2 – the cylindrical centre section with interchangeable warhead; 3 – the aft section, housing the rocket motor.



Sectional diagram of the *Bullpup* ASM-N-7 air-to-ground missile. 1 – guidance system receiver and control system with control valves and with pneumatic servo system for activating the guidance fins; 2 – guidance fins; 3 – warhead; 4 – delta fins, cam-locked to the missile; 5 – rocket motor housing; 6 – thrust nozzle; 7/8 – clips for attaching the missile to the launcher.



control stick, for Left/Right and Up/Down commands.

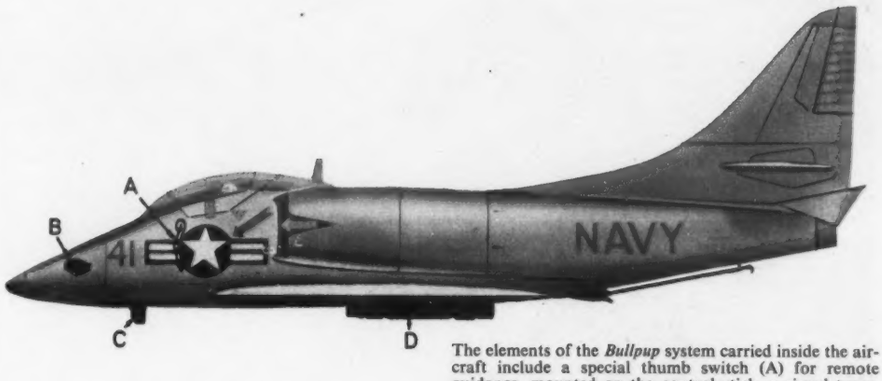
As far as checkout equipment on the ground is concerned, only four small, portable items are necessary, namely one for the missile's entire electrical continuity, another for the rocket motor's igniter circuit, a third for measuring the transmitter power of the aircraft, and a fourth for checking the transmitter signals.

Bullpup's radio command system is quite simple. The guidance signals from the pilot are passed in the form of electric pulses to the aircraft's transmitter, which transforms, modulates, and then transmits them. Owing to a special transmission technique, a relatively high interference/signal ratio is achieved. The relatively low transmission power makes it more difficult for the enemy to home on the carrier aircraft. The signals picked up by the receiver on board the missile are passed via a positional reference gyro (for orienting the guidance system in the air) to the guidance amplifiers. After amplification, these signals are passed to relays, which control pneumatic valves and these, in turn, activate the delta guidance fins. The latter are spring loaded and, in the absence of guidance signals, return to the neutral position.

The receiver in the missile comprises a shock-proof chassis of eight modules, which naturally make use of miniaturised printed circuits. The control package housed in the forebody is also compact and light in weight. Besides the gyro and control valves already referred to, this section includes a compressed gas container (diameter about 6 in) and a dry battery. Castellated joints, held by snap rings, serve to mate the three sections together and permit assembly within a matter of seconds, and are an interesting feature. Each of the four delta wings, which are fastened to the missile during field assembly, has a signal-receiving antenna embedded in the wing itself.

The actual operation of the weapon makes no special demands on either pilot or aircraft. As regards the A version, the procedure is that: When the target is identified, the pilot flies for a brief period in its direction, enters a shallow dive, and launches his missile by pressing a button on the control stick. *Bullpup* then streaks out on a path towards its mark, its guidance system continuously obeying the directional commands received from the aircraft over the radio link. The pilot's task is simply to observe *Bullpup's* flight path and issue the necessary up/down and right/left commands. As carrier aircraft are always armed with several *Bullpups*, the pilot can engage a fresh target as soon as the first missile has struck.

Furthermore, a recently developed novel guidance system, known as the Offset Launch Control System, permits the launching of *Bullpup* from a position parallel to the target, thus eliminating the need to approach it closely. Little is, however, known about this system which has been devised to meet the wishes of the US Air Force in particular. The system is especially suitable where enemy defences are strong or when *Bullpup* is armed with a nuclear warhead. Work on other improvements, aimed at giving the entire *Bullpup* weapon system all-weather capability, has been going forward side-by-side with the new offset system. One such advance, at present under development, would make it possible for the pilot to direct his weapon on the target even when he can do no more than identify it on his radar screen.



The elements of the *Bullpup* system carried inside the aircraft include a special thumb switch (A) for remote guidance, mounted on the control stick, a signal transmitter for the command signals (B), a transmitting antenna (C), and the launcher (D).

To guide *Bullpup* on to its target, the pilot's hand does not leave the control stick, where a special switch is provided to transmit his up/down and right/left commands.

The manufacturer emphasises the high operational safety of *Bullpup*, which appears to have been ensured by incorporating a number of positive safety features in the missile. The rocket motor in the aft section, for example, is so designed that in case of accidental premature ignition—whether in the factory or with the Air Force—it would not fly off in one direction. This is effected by providing a thrust neutralizer which diverts the combustion gases to each side in such a way that the engine casing remains stationary, and this safety device is left in position until immediately before the aircraft takes off. Another precaution is that the two tracking flares are not inserted in the aft section until just prior to take-off. Again, the centre section, which carries the explosive charge, is equipped with a warhead arming device, capable of withstanding the very powerful acceleration and, as in the case of any large projectile, arranged so as not to release the warhead igniter before the elapse of a certain time after launch. A small explosive charge is located in the nose section and, when ignited, closes a switch which sets the battery and the missile's electrical power circuit in operation. This charge is set off automatically, the moment the pilot presses the missile launch switch. Various methods of disposing of his missiles are open to the pilot in an emergency. One is simply to drop the missile without igniting the rocket motor, another to fire the missile with motor switched on but with the warhead unarmed (in this case, the missile is to be directed to an unpopulated area). Yet a third possibility is to jettison missile, launcher, and pylon.

*

The success of the first version of *Bullpup* (US Navy's designation ASM-N-7) led the Navy to place an order with the Martin Company for series production of a slightly improved model, the ASM-N-7A, which has been in service with the Pacific Fleet since 1959. This was followed by the development of an enlarged version—the *Bullpup B*—of which the exact illustration is published here for the first time. *Bullpup B* can be armed with a larger warhead, furthermore its rocket motor is more powerful, resulting in

Two *Bullpup* command-guided missiles being mounted on launchers under the wing of an F-100 *Super Sabre* fighter bomber by means of special vehicles.

In the course of extensive helicopter tests, *Bullpups* (model ASM-N-7A) were launched at ground targets from a US Marine Corps Sikorsky HOS-1 at various altitudes. The missiles were mounted on outriggers on each side of the helicopter's fuselage.

greater range. The nose section with its guidance system, however, remains interchangeable with that of *Bullpup A*.

Over and above these, a new Air Force version, designated GAM-83B and designed to allow a nuclear warhead to be carried, is in preparation. If the training missile described in an earlier issue of *Interavia* is included, variations of the basic type total five, namely:

1 – Bullpup A (US Navy missile, Navy designation ASM-N-7A);

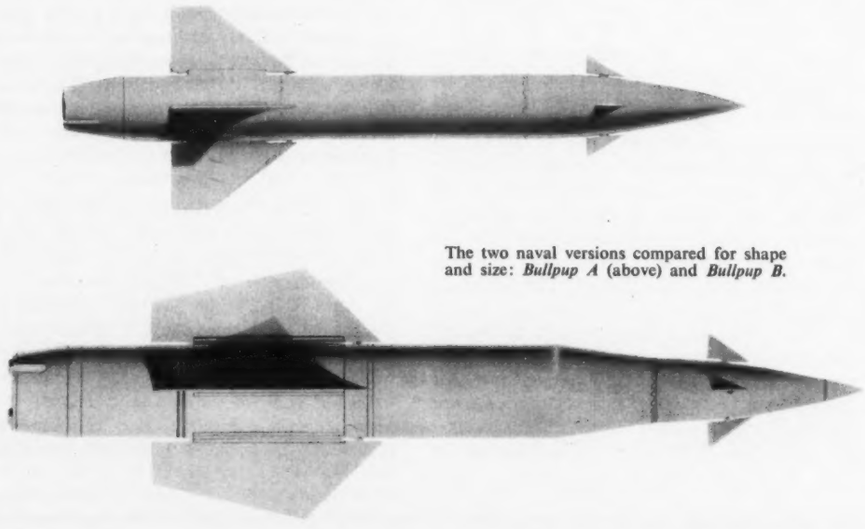
2 – GAM-83A (US Air Force missile with differences in guidance system as compared to Bullpup A);

3 – Bullpup B (US Navy missile with more powerful rocket motor and larger warhead, Navy designation ASM-N-7B);

4 – GAM-83B (US Air Force missile designed for nuclear warhead);

5 – TGAM-83 (training version of the US Air Force missile, described in *Interavia* 6/1960, page 740).

Both A versions are operational, with "B" models well on the way. Martin's *Bullpup A* air-



The two naval versions compared for shape and size: *Bullpup A* (above) and *Bullpup B*.

Technical Data on the Bullpup ASM-N-7A and GAM-83A Versions

Overall Length	11 ft
Diameter	1 ft
Total Weight	571 lb
Weight of Warhead	250 lb

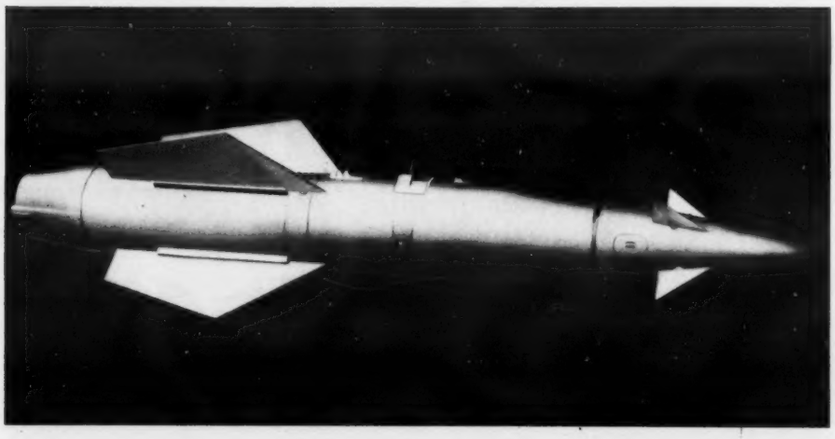
Guidance System: Radio command by means of keyed signal transmitter on board the aircraft.

Powerplant: One solid-propellant motor developed by the US Navy *or* one Thiokol liquid-propellant engine (storable *Patriot* type fuel).

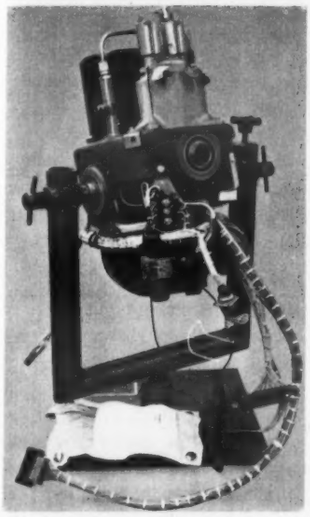
Maximum Speed	About Mach 1.8
Maximum Operational Range	10,000 yds.
Average Operational Range	About 5,000 yds.

The *Bullpup B* version differs from *Bullpup A* in having a more powerful booster motor and an enlarged centre (warhead) section. The geometry of the four cruciform wings has also been altered. Maximum speed and operational range are greater than in the A version; forebody and the guidance system contained are, however, unchanged.

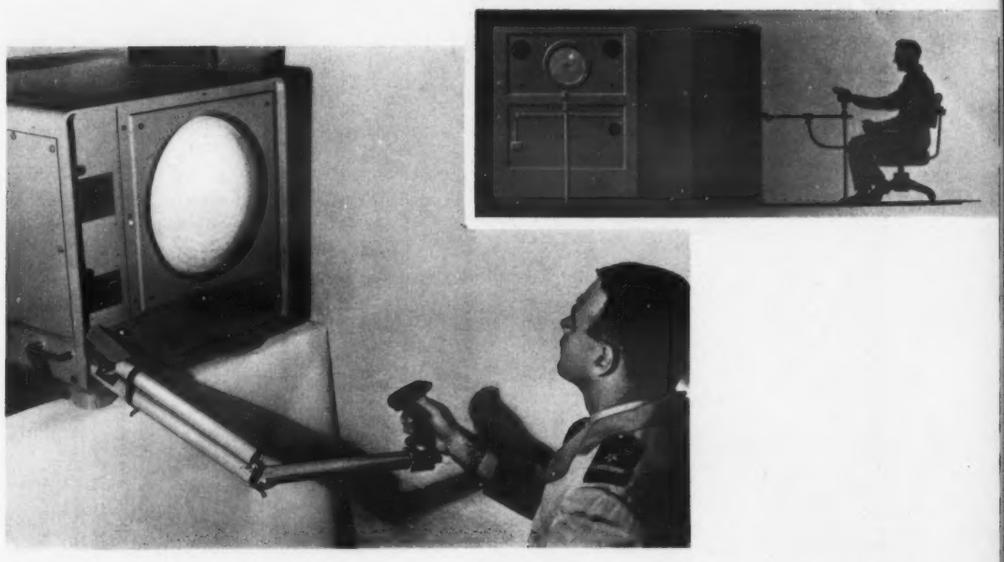
The new *Bullpup B* differs from its predecessor—model *A*—in having a fatter and larger centre section, and larger cruciform trapezoidal wings. The nose section is identical with that of the *A* version, but the span of the guidance fins has been increased.



to-ground missiles are at present in service with Douglas A4D-2 *Skyhawk* and North American FJ-4B *Fury* squadrons. The GAM-83A Air Force version has been issued to F-100 and F-105 squadrons of the USAF outside the USA. The USAF's GAM-83A is identical in size and warhead with the Navy's *Bullpup A* but, as already mentioned, its control system is based on the proportional guidance principle, which differs from the bang-bang principle underlying the naval version. Proportional guidance allows more gradual correction and thus more precise actuation of the control surfaces, resulting in a higher overall precision of the weapon. The GAM-83B, on the other hand, differs fundamentally from the US Navy's *Bullpup B* and must be regarded as a completely new development. The GAM-83B has been subjected to thorough testing at the Eglin AFB missile test facility in Florida, but is not yet operational.



Bullpup's guidance and control system, including receiver, battery, reference gyro, amplifiers, control valves and pneumatic servo system for the four guidance fins. On the underside of the control package can be seen the compressed gas container for the servo system. The bearings for the spindles of the cruciform guidance fins can be clearly seen; two spindles project horizontally into the bearings and retain the control package in the bifurcated frame.



For the low-cost training of pilots in the command-guidance of *Bullpup*, the US authorities placed an order with Radiation Inc., Orlando, Florida, for ground training equipment, designated AN/ARW-T2 *(above* and *left)*. In this system, the missiles flight is simulated on a cathode ray tube, using push button guidance in the same way as the live missile. The flight characteristics of *Bullpup* outside the control of the pilot are electrically generated by the simulator. To speed up *Bullpup* training, the simulator is equipped with an indicator device, on which the accuracy of each "hit" can be read off when the exercise is over.

Extensive launch trials have also been carried out using helicopters, in which a *Bullpup A*, fired from a Sikorsky HOS-1 at an altitude of 1,500 ft, hit a target 10,000 yds distant. The US Marine Corps, responsible for the test, seem to be very encouraged by the results. In most of the trials, the *Bullpup* was guided without difficulty by the co-pilot, the pilot continuing to concentrate on controlling the helicopter. In view of the fact that, at its last Tushino display, the Soviet Air Force demonstrated a new Kamov turbine helicopter with two large-calibre air-to-ground missiles of *Bullpup* configuration, Marine Corps interest in the *Bullpup* programme may well grow.

Martin has recently been working on other air-to-ground missiles, which are encountering US Navy and USAF interest, and may possibly suit NATO. Although these weapons may also be *Bullpups* in name, they should not be expected to have much in common with the missiles described in this article. ←

Development of Guidance Equipment for the Seaslug Missile

By J.M.C. Pinkham, M.A., General Electric Company Ltd., Applied Electronics Laboratories

Over four years ago the Royal Navy decided to equip its County Class destroyers with the Armstrong Whitworth Seaslug *medium-range ship-to-air missile. The first of these guided missile destroyers, H.M.S. Devonshire, was launched in June, 1960 and she is due to go into service next year. The Admiralty has increased its original order for four guided missile destroyers by two, which are to be equipped with the improved* Seaslug II *version. During trials the* Seaslug's *guidance system proved itself so accurate that a small control error had to be deliberately introduced in the test firing, to avoid the destruction of valuable target aircraft and their instrumentation by direct hits, even though the* Seaslugs *were not armed with warheads. No details are yet available concerning* Seaslug II *and its guidance system. Even information on the* Seaslug I *is still to a large extent classified. However, the principle on which the weapon is directed on to its target is known, as are some details concerning the development of the equipment in the missile and the ground-/ship-based checkout equipment. To give our readers an insight into the manifold problems connected with the development of a guidance system of this type, we have decided to present, in abridged form, an article by Mr. Pinkham which appeared under the same title in the "G.E.C. Journal" this Spring.*

The Editors.

In action, the *Seaslug* missile is brought by automatic handling gear from the ship's magazine and loaded into a launcher which is slaved in direction to an auto-follow radar. After launch, the missile is boosted to supersonic speed by four rocket motors which fall away when they have burnt out. The speed of the missile is subsequently maintained by a further rocket motor, forming part of the main airframe. During the boost phase the missile is uncontrolled but, after the boosts have separated, the missile is stabilized in roll and comes under the control of a beam-riding guidance system. A radar on the ship is locked-on to the aircraft target, and signals from the guidance receiver in the missile are used to direct it to fly along the radar beam. The missile then follows the beam until the target is intercepted, when the missile fuze operates and the warhead is detonated.

The General Electric Company Ltd. has been responsible for the development and manufacture of both the guidance equipment and of the automatic test equipment to be used on board ship and in naval supply depots.

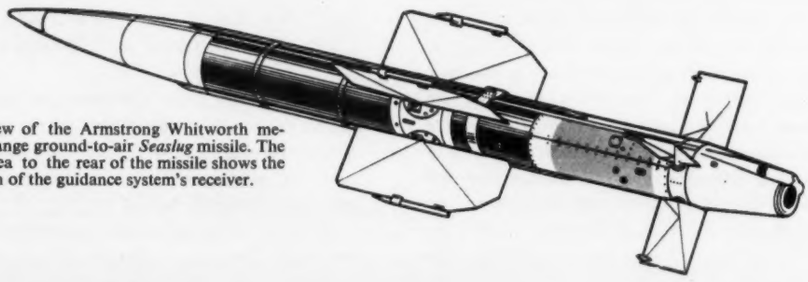
The radar on the ship is an auto-follow conical scan radar. In such a radar, the aerial radiation pattern is off-set from the axis of the radar, and is rotated about it, the frequency of rotation being known as the spin frequency. Any object which is within the space scanned by the beam, but not on the axis, will be illuminated with a signal of varying strength as the aerial pattern is rotated; this is greatest when the radiation lobe is in the direction of the object's misalignment from the axis, and least when the lobe is in the position 180° away. If, therefore, a signal from the radar is received in the missile, the amplitude of the spin-frequency modulation on it will indicate the error of the missile from the beam. In other words, the farther the missile is from the beam, the more pronounced are the variations between the minimum and maximum signal received, and

Seaslug may be used either against high-flying bombers or low-level aircraft. Here the missile is being launched from the guided missile trials ship HMS Girdle Ness.

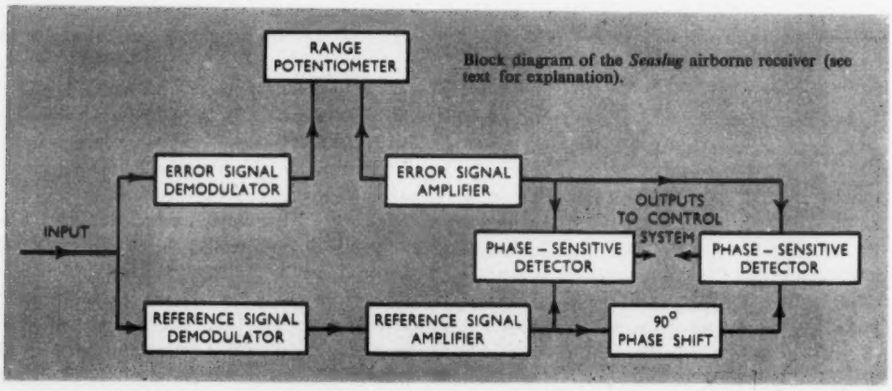
the greater the amplitude of the modulation in the receiver. A signal derived from this modulation can be used as the error signal for a beam-riding guidance loop. The amplitude of the modulation on the received signal is approximately proportional to the error of the missile from the beam over small angles. It is, however, proportional to the angular misalignment and not to the linear displacement of the missile from the beam, which is the quantity required in the control of the missile. A multiplying factor proportional to the missile range must therefore be introduced in order to convert the error from angular to linear terms.

In itself, the amplitude modulation of the received signal provides information about the magnitude of the missile misalignment from the axis only and, before the missile can be controlled, a further piece of information is required to provide a space reference from which the direction of the misalignment in the up/down-left/right plane can be deduced. This space reference is sent to the missile by modulating the radar transmission with a signal derived from the position of the radar aerial spinner. By comparison in the receiver of the relative phases of the amplitude modulation and this reference modulation, it is possible also to derive the direction of the missile's misalignment from the beam.

The function of the equipment is to provide output voltages corresponding to the distance of the missile from the centre of the radar beam in the up/down and left/right directions, and these voltages are interpreted by the control equipment as demands for accelerations, and hence for fin angles, to bring the missile back to the beam centre.



Side-view of the Armstrong Whitworth medium-range ground-to-air *Seaslug* missile. The grey area to the rear of the missile shows the location of the guidance system's receiver.



Block diagram of the *Seaslug* airborne receiver (see text for explanation).

The guidance equipment in the missile comprises two main units, namely a receiver and an aerial assembly. The polar diagram of the rearward-looking aerial is made wide enough to allow for variations in missile attitude to the line-of-sight from the radar, and the assembly includes a controllable ferrite attenuator, used as a protective shutter when the missile is immediately in front of the radar just after launch, and subsequently forming part of the receiver automatic gain control loop.

The arrangement of the computing circuits of the receiver is shown below. The error-signal demodulator extracts the modulation imposed on the received signal by the radar scan. This is a sine wave, the amplitude of which represents the angular misalignment of the missile from the beam. The multiplying factor proportional to missile range is provided by a potentiometer, known as the range potentiometer, which is part of the missile control equipment.

The speed of rotation of this potentiometer is chosen to correspond with the range performance of the missile and the error sine wave is fed through the range potentiometer before being taken to an amplifier. A second demodulator extracts the reference signal (sent as a modulation of the radar transmission) and this is amplified and filtered to give a reference sine wave.

The error sine wave, now representing linear displacement of the missile from the beam centre, is fed into a phase-sensitive detector with the reference signal, and this detector is such that its output represents the amplitude of the component of the error sine wave which is in quadrature with the reference signal. At the same time, the reference signal is taken to a 90° phase-shift circuit, the output of which is fed, with the error sine wave, to a second phase-sensitive detector. The two detector outputs are voltages representing linear missile displacements from the beam in two orthogonal directions, and constitute the input signals to the missile control equipment.

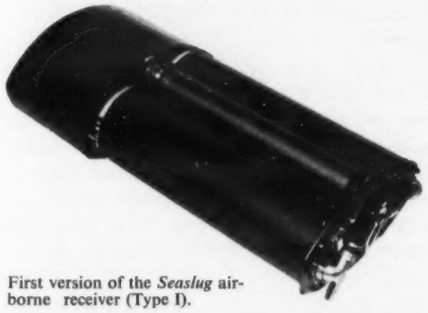
A high-pressure gas generator in the missile provides the power for the hydraulic system and also drives a 2,400 c/s, 115 volt, single-phase turbo-alternator.

The first *Seaslug* missile receiver, designated Type I, consisted of three main units: a microwave receiver, a power unit, and a circuit unit. The microwave receiver and some associated circuits were contained in a cast box occupying the full cross-section of the compartment; the other two units were cylindrical with thin removable covers, and were sealed at each end by inflatable rubber rings. A fourth unit, a thin cylinder lying between the power and circuit units, contained the range potentiometer which in this design—unlike subsequent ones—was included in the guidance equipment.

Equipments of this design were used in early missile firings, but the majority of the research and development trials in which the guidance system was proved in flight were carried out with the Type II receiver, the prototype for the final service equipment.

Although its electrical design was in some ways similar to that of its predecessor, the Type II receiver was contained in one box. The microwave receiver and the power pack occupied the central well in this chassis, and the valve circuits were arranged down each side. Each circuit sub-unit consisted of a main board on which were mounted the rugged sub-miniature valves used, developed specifically for guided weapons use, and a resin-cast block containing the components. The receiver box was pressurized and sealed by a rubber gasket round the lid. Connectors on the two end faces of the box carried the operational connexions to other parts of the missile as well as the connexions for telemetry. The floor of the main box, which was to the outside of the missile when the receiver was installed, carried test sockets which could be used initially for testing the receiver itself, and subsequently for testing the receiver in the missile after they had been made accessible through a removable panel in the missile skin.

The Type IV guidance receiver is the version for both the acceptance trials and the operational



First version of the *Seaslug* airborne receiver (Type I).

Seaslug missile. It is similar in basic principles to the Type II, to which it bears an obvious resemblance, but from which it differs in some mechanical and electrical details.

The main receiver box is of different design from that of the Type II receiver, and the webs carrying the valve holes have been incorporated into the outer walls of the box. The microwave receiver has been redesigned so as to form a major sub-unit, which can be removed in one piece. It is the same with the power pack, and the sub-units for the four main h.t. supplies are likewise mounted on one removable chassis. As in the case of the Type II receiver, resilient mountings are used in order to mitigate the effect of vibration in flight. The Type IV receiver design incorporates printed wiring in circuit sub-units and in the main interconnecting cableforms between them.

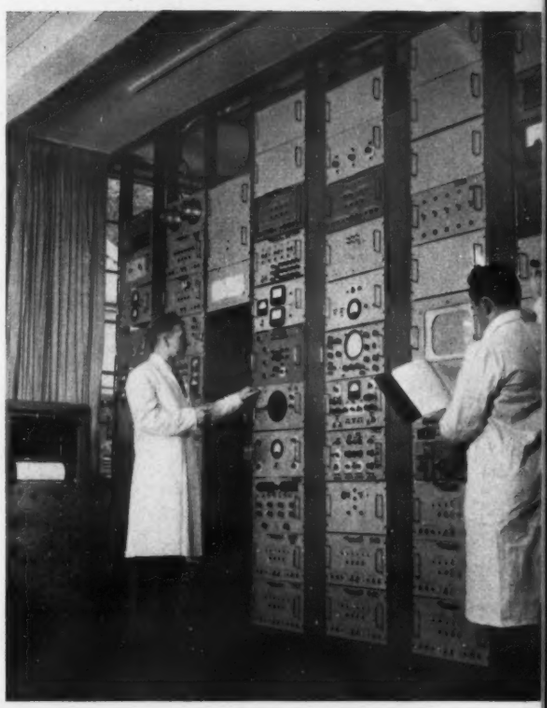
Owing to the complexity and expense of operating missile equipment in its proper environment, namely in flight, extensive use must instead be made of ground testing at all stages of development. Such environmental testing naturally emphasizes shock and vibration, both likely to be severe in missile flight.

The principal safeguard against equipment failure under vibration is the avoidance of sharp resonances of the main structure or of individual components, and in the designing of a receiver a resonance search is first carried out. This is normally followed by a functional test, in which the receiver on its mountings is subjected to a range of frequencies extending beyond 1 kc/s, at peak vibration accelerations which may at times be greater than 15 g.

The rate of rise of the initial acceleration of the missile by the boost motors is very steep and the performance of receivers under impulsive shock is therefore examined in drop tests. A receiver is mounted in a special cradle carrying a spike (diameter $^3/_4$ in), which is dropped on to a lead block in which the spike embeds itself. The height of the drop determines the magnitude of the shock produced. Tests of receiver performance under sustained acceleration are made on a large centrifuge. All the normal climatic and storage life tests laid down for service equipments are also carried out.

(It was reported some time ago that, as a result of an aircraft collision, one of the *Seaslug's* electronic components crashed to the ground from a height of about 30,000 ft. Thorough testing carried out after this crash on this physically bent and distorted unit revealed that all but one of its many functions met the full acceptance test specification. — The Editors).

Simulation of *Seaslug* beam-riding guidance problems has been carried out on large analogue computers designed and built at the Stanmore Laboratories of the GEC. The *Neptune* simulator

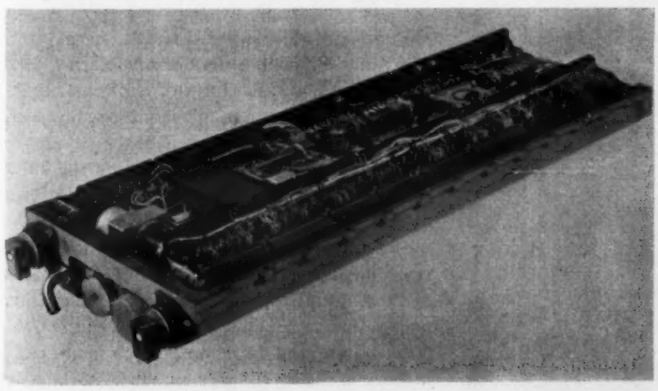


The *Neptune* simulator was designed by the General Electric Co. especially for use in the development work on the *Seaslug* Guidance System.

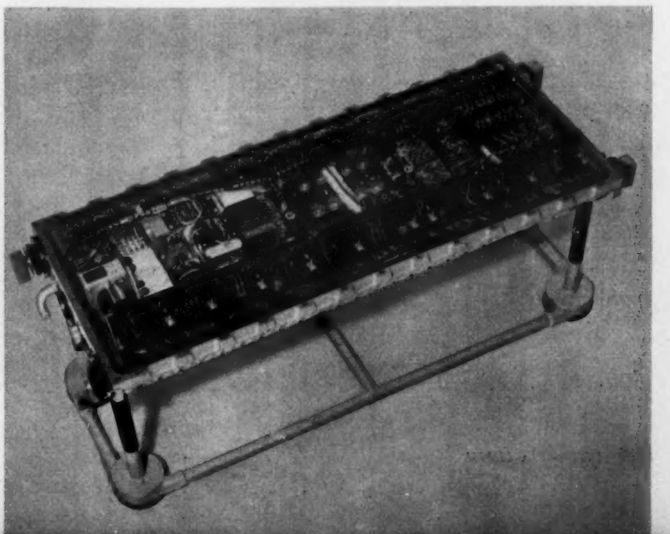
was built specifically for this work, and was the first to be put into operation. It contains approximately 100 computing amplifiers. The other simulator, *Stardac*, was built as a general-purpose computer with 200 amplifiers and has been used on a number of projects, to which *Seaslug* was added when extra capacity was needed for the simulation of low-angle trials.

Each simulator contains function generators representing the radar conical scan, and models of the effects of sea reflections. The output from these units represents the waveform of the signal which would be received by a missile at a given point in space, and is used to modulate a signal generator, so that the resulting output is the same as the signal which would exist in the supposed missile receiver. It is possible to include actual missile equipments in the simulation but because of the need to have ready access to all circuits

It was decided to house the Type II receiver in a single chassis, along both sides of which are set the valve units.



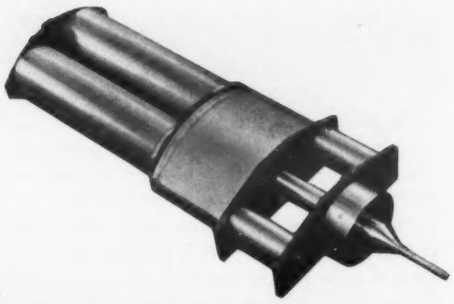
Type IV is the final version of the *Seaslug* receiver. The valve units are made up of printed circuits as are the principal connections between them.



so that experimental changes can be easily introduced, the receiver generally used is a special rack-mounted version of the missile equipment, operating from the standard 50 c/s mains supply. The control equipment and the aerodynamic properties of the missile are simulated in an analogue fashion, and the loop is then closed by feeding back to the beam function generator the signals representing missile motion and position. The initial conditions of dispersion, missile characteristics, and beam motion are set in for each run, and the subsequent simulated flight recorded on pen-recorders.

A large part of the simulator work consists of the investigation of the effects of proposed changes, and the evaluation of overall performance. Individual firings will be simulated, either to check the correspondence between the simulator and reality, or to provide evidence for the investigation of apparent peculiarities in the flight performance of a missile.

Information relating to the performance of the guidance equipment in flight is, in the main, obtained from two kinds of instrumentation,



The *Seaslug* receiver, cradled as shown, is tested for resistance to severe shock by dropping from various heights onto a lead block.

namely dish cameras and telemetry. A dish camera is mounted on the radar aerial director, and set in such a way that the camera axis is accurately aligned with the axis of the radar beam: flares are fitted to the missile to give better visibility on the camera films. The dish camera records carry timing marks and the misalignment of the missile from the beam at the time in question can be calculated from the measurement of the position of the image of the missile flares in a camera frame.

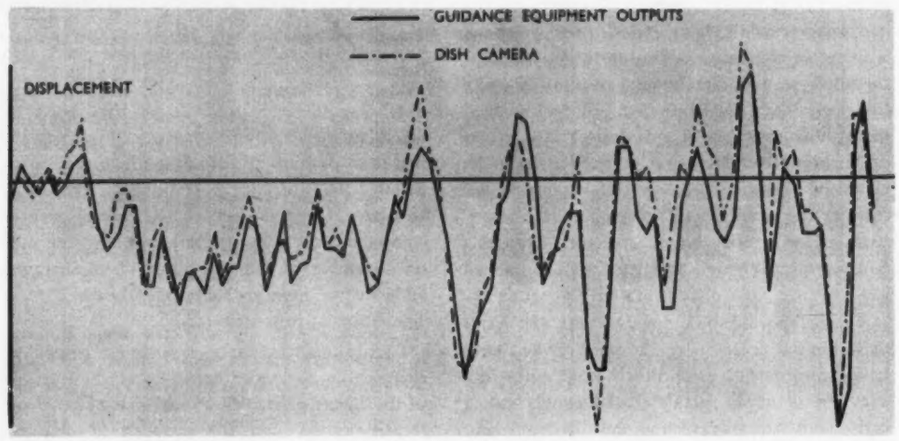
This independent measure of missile displacement can be compared with the telemetry record. One or more telemetry senders are installed in each missile to transmit information to special telemetry receivers and recorders on the ground.

Many trials of a beam-riding guidance system can be carried out without an aircraft target, as the radar aerial can be programmed to have the appropriate movement, for example for an interception involving gathering at low angle in the presence of sea reflections. The performance of the missile must however ultimately be confirmed with the radar operating against a real target, and sufficient target interceptions must be carried out to provide the information required for the proving of the missile fuze; there must also be some firings with live warhead. The drone targets used have wing-tip pods which carry cameras to photograph the missile during the interception phase. For trials held in Australia, where recovery of the missile is possible, a small missile-borne single-shot camera developed by the Australian Weapons Research Establishment is also sometimes used. This can be connected to the missile fuze and takes one exposure at the instant the fuze triggers.

The test gear used for receiver preparation during research and development firing trials is operated by trained engineers familiar with the guidance equipment and with the overall missile system. The requirements of the Royal Navy for the testing of missiles in operational use are very different, the prime purpose being simply to ensure that a weapon is fit to fire within the performance tolerances laid down: it is clearly impracticable to provide testing staff highly trained in every detail of the missile equipment, nor can a large amount of time be devoted to the testing of an individual missile on board ship. The test equipment designed and built for naval use has accordingly been made automatic in operation, and tests on a Go/No-Go basis.

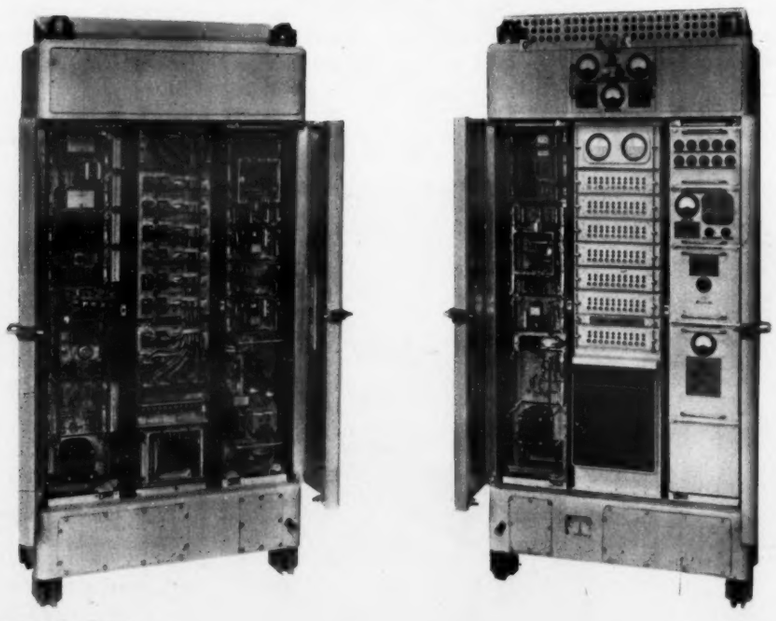
The console allows the selection of any of the guidance equipment tests or overall missile tests. Each test is separately initiated by pressing a button on the control panel: the test is then automatically carried out and the result indicated by the lighting of a pass or a reject lamp adjacent to the press button. This automatic test equipment is of necessity no less complex than the missile equipment, and it contains, for instance, over 300 valves. In short, its development has been a major project in itself.

When the development of *Seaslug* started, little was known about the form of electronic equipment suitable for use in missiles. Now, however, designs for new projects can be based on the experience accumulated as well as on the latest technical developments. The future equipments already envisaged will be largely based on the use of transistors. This, coupled with the introduction of printed wiring and more automatic methods of assembly, will increase reliability, and at the same time decrease weight, power consumption, and the complexity, to some extent at least, of the equipments required. ⟷

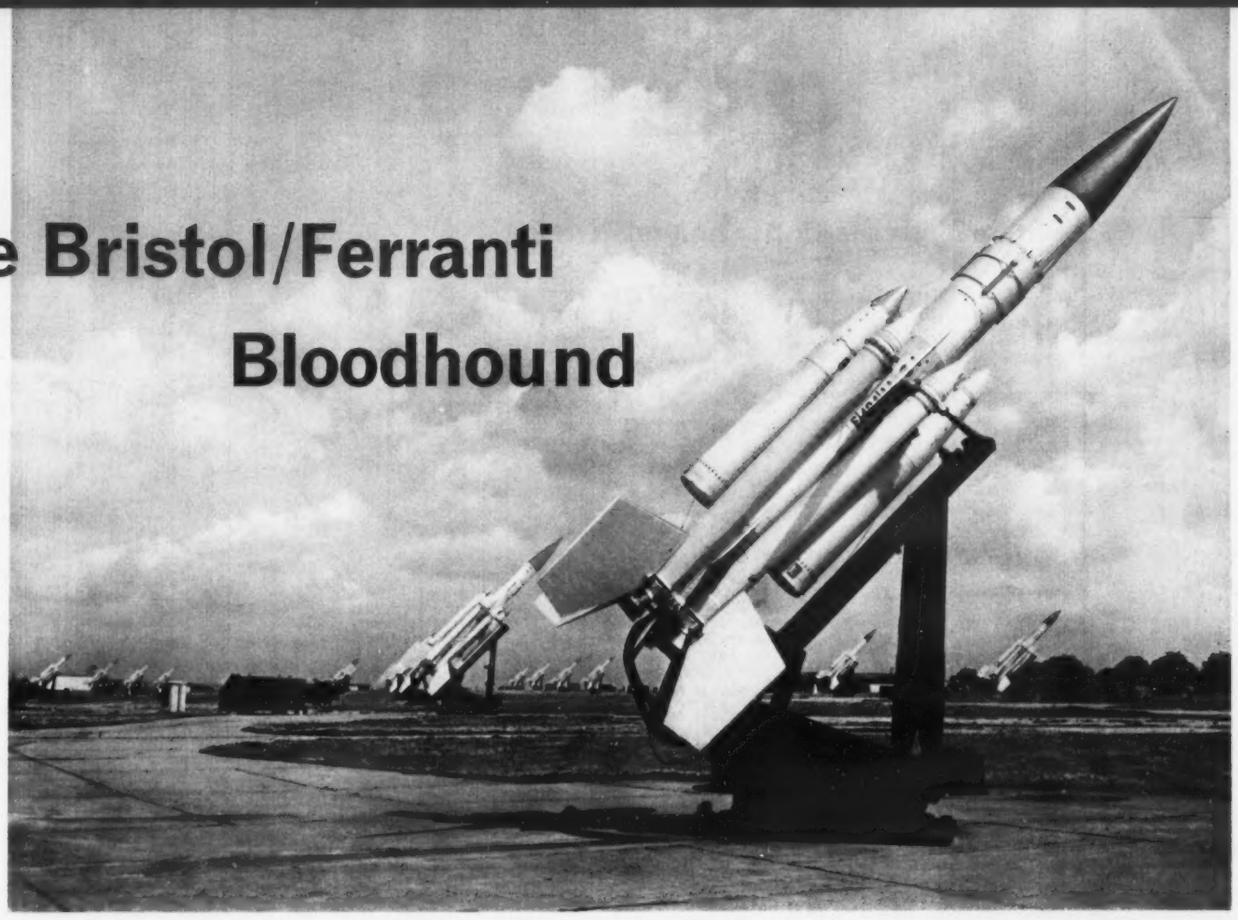


Comparison of values recorded during a test firing of the missile by a dish camera (dashed line) and by telemetry (solid line).

Shipborne automatic check-out equipment to test the service readiness of the *Seaslug*.



The Bristol/Ferranti Bloodhound



By D. J. Farrar, O.B.E., M.A., F.R.Ae.S. Chief Engineer, Guided Weapons, Bristol Aircraft Limited.

With the announcement in July of a substantial order from Sweden for the Bristol/Ferranti *Bloodhound Mark 2* and with the decision of the Swiss Federal Council to recommend its adoption for the defence of Switzerland, the *Bloodhound* was clearly confirmed in its position as Europe's most important guided weapon system.

Bloodhound 2 is already on order for the British Royal Air Force, while the earlier *Mark 1* version is deployed in very considerable strength in the United Kingdom and has been adopted, on a smaller scale, by Sweden and Australia.

No other European missile system has gained acceptance on such a scale, and the decisions of the Swedish and Swiss authorities to adopt *Bloodhound 2* are particularly significant, as neither country is committed by external treaty obligations, and thus each could base its selection of defence equipment in the sole criterion of technical merit. Their choice is therefore a clear-cut vindication of the basic concept of the sophisticated *Bloodhound* system.

Many aspects of the Mark 2 *Bloodhound* surface-to-air missile system cannot yet be told. It is, of course, a direct development of the Mark 1 which has been in operational service with the RAF for the past three years. The intensive development programmes of the past few years are reflected in all-round improvement of performance, deriving chiefly from the adoption of continuous wave radar guidance in place of the pulsed radar system used in *Bloodhound 1*.

The adoption of CW radar guidance has not only enabled *Bloodhound's* operational range to be significantly increased, but also given it great lethality against all types of target from high altitude down to very low levels, even in the face of highly sophisticated electronic counter-measures. The ground radar set developed for use in the Mark 2 system is, in fact, the most accurate and advanced in the world.

Bloodhound 2's efficacy against the low-flying attacker—hitherto the Achilles' heel of air defence—has been demonstrated during firing trials. Details released of one the many successful test flights already carried out revealed that it resulted in the interception and destruction, by an unarmed missile, of a fast jet target flying at less than 1,000 feet.

In the field of tactical control, other improvements have been made. The launch control post—the main operational link between the battle control centre and the missiles themselves—is built around a compact digital computer, with a consequent gain in speed of response and operational flexibility.

A new version of the Bristol Siddeley *Thor* ramjet gives the missile even better range and altitude performance; full advantage has been taken of recent technological advances, and of the experience gained with *Bloodhound 1*, to improve still further the efficiency, reliability, and serviceability of the weapon system as a whole. Fundamentally, however, the roots of its outstanding performance and reliability are to be found in features which have been basic to the design concept since its earliest days.

The most important of the general requirements behind the choice of a semi-active homing guidance system were those of high fire-power and the use of tracking radars which would not impose major radar development problems. To achieve long range, the guidance system had to be one that would permit much of the missile flight to be at high altitudes; for accuracy of interception, the use of homing was essential.

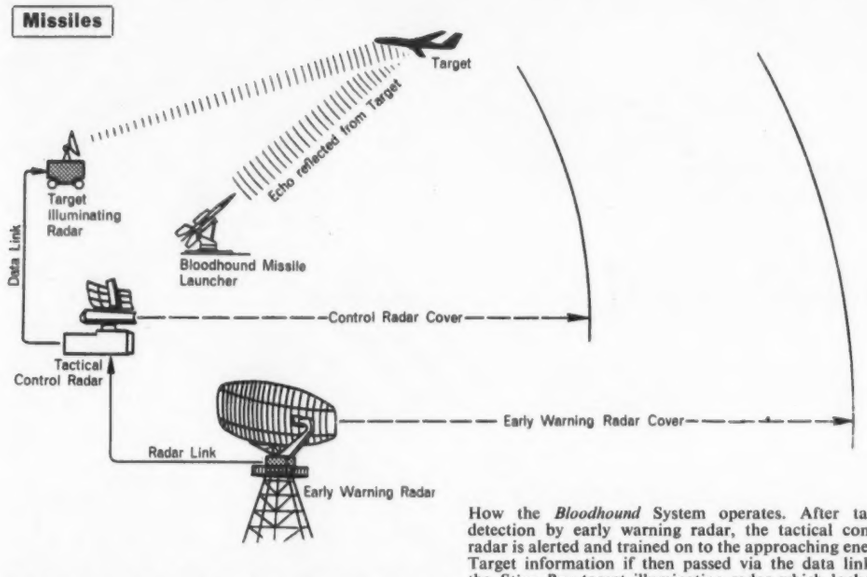
All these requirements were met by employing semi-active homing from launch. In this system, the target is illuminated by a ground radar, while a receiver in the missile is locked on to the reflected signal from the target. The missile is not then constrained to follow a "line-of-sight" trajectory, and fire power not limited by the number of radars available.

The target illuminating radar used in *Bloodhound 1* is the *Sting Ray* radar, a very accurate automatic, pulse-radar system developed by Associated Electrical Industries Limited. At that time, while the advantages of continuous wave radar were appreciated, development had not reached a stage where the potential benefits outweighed the immediate availability of highly efficient pulse-radar systems.

The need for long range also helped to influence the choice of the method of propulsion. Even at short ranges, the ramjet appeared to be competitive with the rocket. Over longer ranges, it held distinct advantages, and, because of its lower propellant consumption, it offered the prospect of achieving further extensions in range without major re-design of the airframe. These considerations, plus such other factors as the ease of handling and storing the simple and familiar kerosene fuel, led to the adoption of ramjet propulsion, despite the fact that—at the time the decision was taken—ramjet experience was limited and supersonic ramjet propulsion had not been achieved in Britain.

When a second working party was formed to study possible airframe configurations, therefore, two requirements had already been established. Many possible configurations were studied, and it was a year before a final decision was taken. There is no doubt that this period of relatively unhurried study at the most formative stage of the project made a decisive contribution to the subsequent progress through development and into production and service.

One of the first questions the "engineering working party" had to answer was "How many ramjets?" The choice was a multi-ramjet configuration versus a single-ramjet configuration employing either an intake in the missile nose or



How the *Bloodhound* System operates. After target detection by early warning radar, the tactical control radar is alerted and trained on to the approaching enemy. Target information if then passed via the data link to the *Sting Ray* target illuminating radar which locks on and follows the target. After launch the *Bloodhound* homes on reflected radar signals from the target.

intakes in the side of its body. Both single-intake versions were eventually ruled out, the first because it gave insufficient space for the guidance equipment and raised vibration problems, the second because of the lack of experience with such a configuration in interceptor missiles.

Once the multi-ramjet concept was accepted, there remained the question "how many wings?" and whether fixed or moving. Comparative studies were made of a number of "paper designs," combining fixed or moving wings with two or four ramjets, and cruciform or monoplane wing configurations.

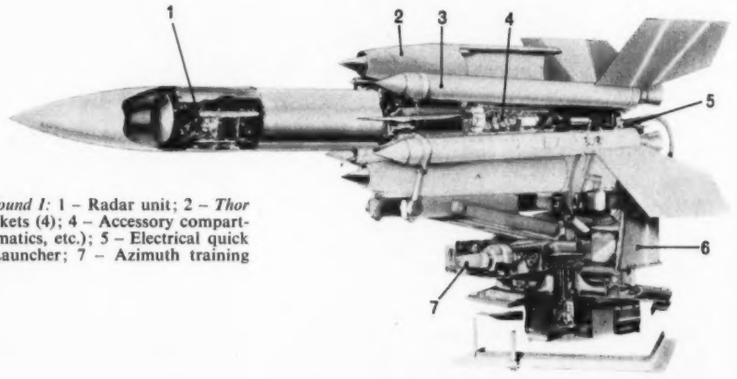
Among the factors to be considered were radome aberration and missile manoeuvrability, particularly at high altitude. These were to some degree inter-related and inter-acting, and the good high-altitude performance of *Bloodhound* depended on them.

A supersonic missile which flies for any distance must, if weight and cost are to be economic, have a streamlined radome in front of the homing eye or dish. This radome causes distortion of the radiation reflected from the target, which manifestes itself in an erroneous line of sight. If the radome is rotated in space, the line of sight erroneously rotates as well, conveying to the missile false steering signals which could have a very serious effect at high altitude. Careful control of radome manufacturing methods will, of course, do much to minimise the distortion but will not entirely eliminate it.

As regards manoeuvrability, the main problem in an interceptor missile is to strike the right compromise between available manoeuvre and time required to develop that manoeuvre, especially at high altitude. Abrupt and violent changes in body incidence as the missile changes its attitude in response to manoeuvre demands can also have unwelcome effects on the ability of the homing eye to "hold" its target.

An example of the conflicting demands which are made by the requirements of guidance efficiency and missile manoeuvrability is the compromise necessary between wing size and guidance eye size. The former obviously governs manoeuvrability at altitude, but on the other hand increased homing eye size will give better target position information which will, in turn, decrease missile manoeuvre demands. Since increasing homing eye size also improves the range of target detection, the policy on *Bloodhound 1* was to favour, so far as possible, the demands of the guidance dish.

Comparison of the various paper designs showed that, for a given missile weight, the number of ramjets made little difference to performance.



Elements of the *Bloodhound I:* 1 – Radar unit; 2 – *Thor* ramjet; 3 – Booster rockets (4); 4 – Accessory compartment (hydraulics, pneumatics, etc.); 5 – Electrical quick connector plug; 6 – Launcher; 7 – Azimuth training motor.

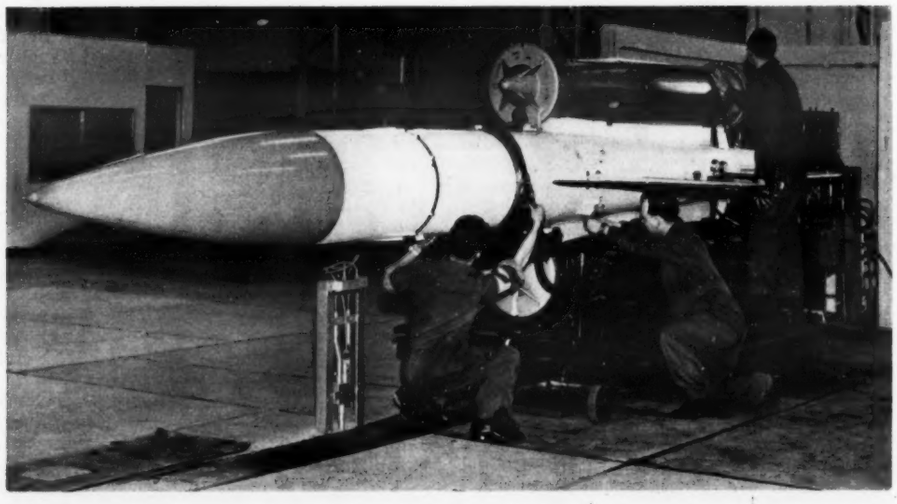
On the score of available manoeuvre, the monoplane fixed wing gave the best results, with little to choose between the cruciform fixed wing and monoplane moving wings. Moving wings gave much shorter response times, however, and the fixed wing designs suffered more from radome aberration effects.

The choice of a monoplane configuration for a guided missile was undoubtedly unorthodox. All other British missiles of that time had fixed, cruciform wings and moving rear control surfaces. There were, however, substantial arguments in favour of adopting the "twist and steer" method implicit in the monoplane configuration.

A Cartesian missile manoeuvres so as to achieve a collision course in each manoeuvre plane. A twist and steer missile rolls so as to align the normal to the wings with the vector direction in which manoeuvre is required and then develops that manoeuvre by pitching. In the Cartesian missile, miss distance can be increased by missile response lags and by cross couplings, such as those between pitch and yaw affecting the roll stabilisation upon which the system fundamentally depends. In a twist and steer missile, the only major cross couplings are gyroscopic forces.

The twist and steer arrangement—which is that found in birds—also possesses the advantage of being redundant, in that a failure of either

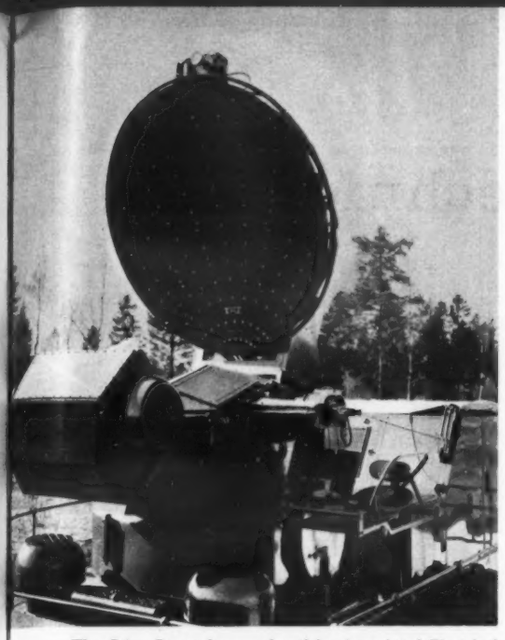
Technicians of the Royal Air Force service a *Bloodhound*. The missile is seen in its flight configuration with the rocket boosters detached. Two of the forward shoes, which allow the booster cases to detach when the thrust diminishes, can be seen by the leading edge of the wing.



A Mainstay for Switzerland's Anti-aircraft Defences

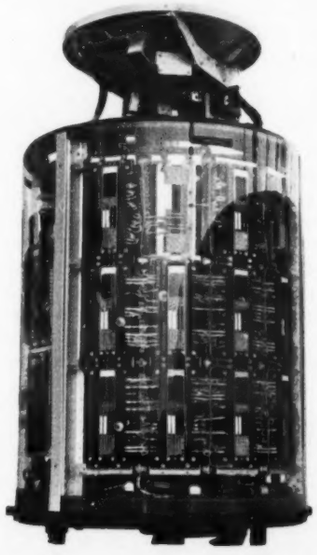
On July 14th, 1961, the Swiss Federal Council asked Parliament to approve a bill providing Sfr 300 million for the acquisition of the Bristol/Ferranti *Bloodhound Mk. 2* ground-to-air guided missile, and a further Sfr. 150 million for medium-calibre AA guns. As already published, *Bloodhound Mk. 2* missiles can effectively attack targets up to an altitude of about 60,000 ft; range is some 70,000 yds. Two Swiss AA artillery regiments, each of four units, are to be equipped with this missile.

On September 19th, 1961, when the Swiss Parliament approved these appropriations, Divisional Colonel Etienne Primault, Chief of Aircraft and Anti-Aircraft weapons, made the following statement on the value of *Bloodhound:* "The choice of *Bloodhound* by our experts is certainly the best we could have made, with regard to both the number of batteries which can be at present established with present resources and the role which we require of this weapon. Its long range compensates for the disadvantage of fixed location. Admittedly, in the case of the employment of anti-aircraft guided missiles there is much dead ground, especially in the mountains. The task of the AA guns and aircraft will, therefore be to complement the guided missiles."



The *Sting Ray* radar, produced by Associated Electrical Industries. The radar dish and horn tilt as a complete unit and the pedestal is mounted on a rotating base.

The radar dish and guidance set of the *Bloodhound*, developed by Ferranti Ltd. The sub-unit construction is clearly to be seen.



pitch control or roll control can still permit some sort of interception course, whereas failure in one plane of a Cartesian missile is catastrophic.

The three basic characteristics of the first *Bloodhound* missile were now established: semi-active homing guidance, propulsion by twin ramjet engines, and a moving-wing monoplane configuration. Design and development could now begin and, although difficulties were encountered, the basic conception proved sound and the *Bloodhound 1* was brought into full production.

The missile flies a proportional navigation course (i.e., one in which the rate of turn of the missile flight path is proportional to the rate at which the sight line of the homing eye to the target changes). Thus, although the homing receiver dish always points directly at the target, the missile axis does not normally do so, but points at an interception point some way ahead of the target.

Radar signals reflected from the target are collected by the receiver dish, and the receiver ensures that the dish locks on to and tracks the target and that a signal is sent to the wing servo to move the wings and steer the missile on an interception course. It does this by resolving the signal received into pitch and yaw components, which are then compared to obtain the roll signal. (All the computation involved is, naturally, automatic within the missile). This signal operates the wing differentially to roll the missile to the required attitude, and the pitch signal is applied to the wing servo in the same sense to operate the wings symmetrically and pitch the missile on to its computed interception course. The two manoeuvres take place simultaneously, of course, and are constantly corrected as the missile closes with its target.

Early flight trials proved that *Bloodhound 1* could satisfactorily counter evasive action on the part of its target, and indeed it is the essence of a homing system that the accuracy of information available for interception increases as the distance between missile and target decreases.

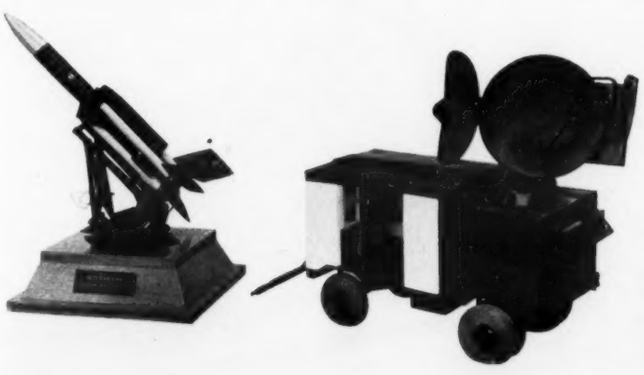
The response of the missile to manoeuvre demands is, as has been mentioned, very quick. The basic interval of response of the pitch loop is the time needed for the powerful wing servos to put on a wing angle, and response speed is therefore very fast. In roll, very powerful roll moments are applied by the differential operation of the wings. Since the roll moment of inertia is of a much smaller order than the pitch and yaw moments of inertia, very high roll accelerations and rates can be achieved. Since there is no stability problem analogous to weathercock instability, the roll system can in practice be made much faster then the pitch system. Moreover, by altering the gain of the roll loop with altitude, the roll response of the missile can be maintained almost independent of height.

Since the centre of gravity of the missile and the centre of pressure of wing lift are very close together, little body motion is induced by the manoeuvres of the missile, which alters course with a minimum change of body incidence so that guidance receiver dish is not forced to contend with violent changes in the line of sight to the target.

Many hundreds of test firings, plus a considerable number of RAF firings under operational conditions, have proven *Bloodhound 1's* ability to maintain precision of control and accuracy of homing out to very long range and at very high altitudes. Frequent RAF and NATO exercises have demonstrated the reliability and speed of response of the weapon system as a whole, and have proven that this sophisticated weapon system is capable of being fitted into any modern scheme of air defence.

In the Mark 2, *Bloodhound's* capabilities are still further extended. The radars, electronic equipment, and other elements of the *Mark 2* system have already completed arduous test programmes, and development is advanced.

In lethality, speed of reaction, and flexibility of operation *Bloodhound Mark 2* is a formidable anti-aircraft defence system, capable of countering any threat by enemy aircraft for years to come. ←←



The *Bloodhound Mk2* weapon system in model form. The radar trailer carries the antenna of the continuous wave target illuminating radar.

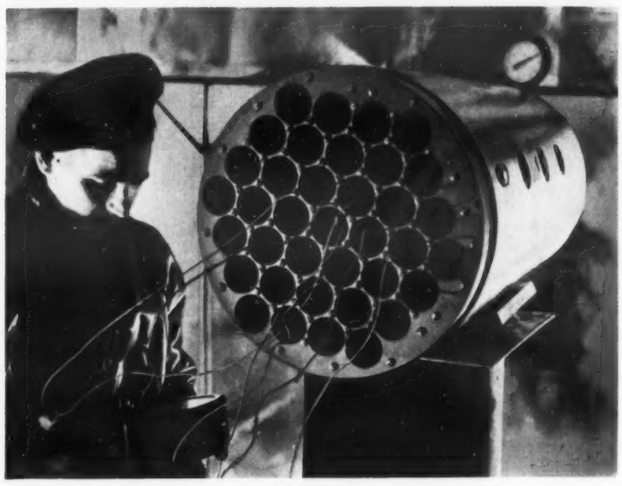
Equipment · Materials · Techniques

When mention is made of "equipment," the manufacture of which accounts for an ever-increasing proportion of the aviation industry's order book, one generally thinks almost exclusively in terms of electronics. But it would be a mistake to let oneself be "dazzled" by cathode ray tubes and to overlook the countless products of the non-electronic equipment industry... from the smallest valve to complete hydraulic systems, from aircraft tyres to complete landing gear, and from aluminium to high-temperature resistent nimonic alloys.

Although Interavia *has always published numerous articles in this field, there has until now been no systematic reporting on new equipment, materials, and techniques.*

For obvious reasons, our new section lays no claim to being exhaustive. The task we have set ourselves is to present a small selection of the more significant developments all over the world.

On this occasion, bearing in mind the recent SBAC Show at Farnborough, we are devoting our space to British products exclusively. In future, however, we shall normally be presenting an international selection. The Editors.



Rocket launcher in glass fibre, produced by Microcell Ltd. to a British Government specification.

Normalair Ltd., Yeovil is responsible for the design and production of the cabin pressure control system and liquid oxygen installation in the Vickers VC.10. One of the advantages of electro-pneumatic actuation of the pressure control system is that the need for long pneumatic pipe runs is eliminated, and good flow distribution is ensured among the widely separated discharge valves. This system also enables very precise regulation of cabin pressure. These capsules serve as pressure sensing elements, each actuating a transducer. The signals are taken to an amplifier, where they are combined to form a resultant control signal to the discharge valves. In flight, the cabin pressure altitude and the rate of pressure change are controlled by means of a selector unit on the flight deck. The Vickers VC.10 will be the world's first passenger airliner in the world to be fitted with liquid oxygen storage equipment for emergency use. A feature of the 35-litre vacuum-insulated converter (see illustration) is an automatic reserve circuit which—regardless of passenger consumption—guarantees an oxygen supply to the crew members. The combined storage tank and converter has a maximum diameter of 18 in, an overall height of 19 in, and weighs 138½ lb fully charged.

*

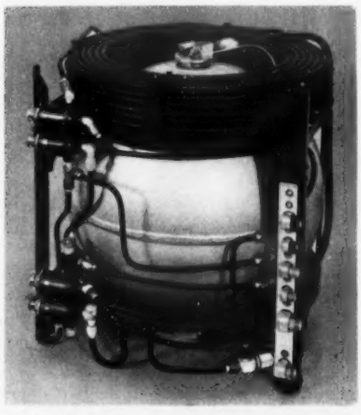
Glass fibre was the material selected by *Microcell Ltd, London*, as the material for its rocket launcher. Designed for launching of 2-inch air-to-ground and air-to-air ballistic rockets, these launchers are being currently produced in four different versions: two retractable launchers forming an integral part of the fuselage, for 14 or 24 rockets, and two models to be mounted under the aircraft wings, for 24 or 37 rockets. These launchers, developed to British Government specifications, are already being fitted on RAF *Lightnings, Hunters,* and *Canberras,* as well as on the Royal Navy's *Sea Vixens* and *Scimitars.* The Royal New Zealand Air Force also recently ordered a large number of 37-tube launchers (under-wing type) for its *Canberras.* Among the main advantages of glass fibre construction are economy in manufacture, storability for long periods without deterioration, and absence of corrosion. Illustrated is a 37-tube launcher being tested under simulated tropical conditions in a Microcell laboratory at Blackwater.

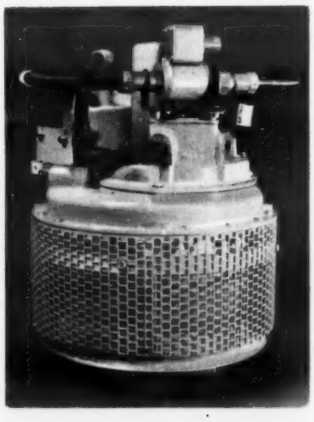
Boulton Paul Aircraft Ltd., Wolverhampton, manufactures the hydraulic power units for the Vickers VC.10 controls, which comprises four aileron units, four elevator units and three rudder units. Each unit consists essentially of a standard hydraulic pump and a ram which directly actuates a portion of a control surface. Operation is both mechanical and electrical. These controls are built from a common basic unit, and are therefore readily interchangeable, an advantage in respect of maintenance and spares. Details worth noting are a relief valve and damper valve. The former holds fluid pressures below 2,000 lb/sq.in., and the latter ensures that, in the event of a failed unit, the control surface will trail to a "no-load" position. Also, two units in each group are linked to the aircraft's auto-pilot system by integral autostabilizer/auto-pilot actuator. The weight of a unit, complete with auto-pilot equipment and electric motor and filled with hydraulic fluid, is in the region of 80 lb.

*

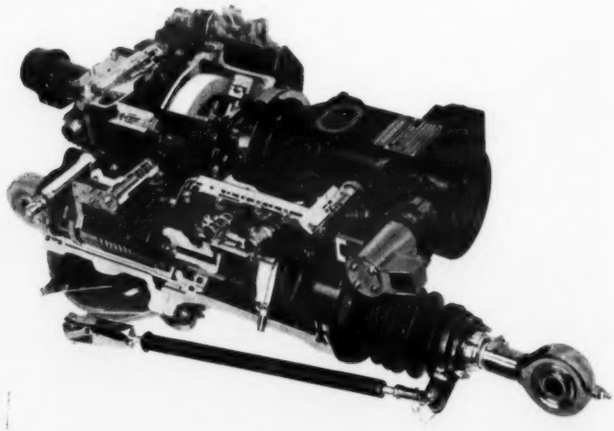
Henry Wiggin & Co. Ltd., Birmingham, offers its materials for electro-thermal de-icing installations under the trade name *Brightray.* These nickel-chromium and nickel-chromium-iron alloys have

Two items of equipment for the Vickers VC.10 developed by Normalair Ltd. *Left:* A 35-litre converter for the emergency supply of oxygen to passengers and crew. *Right:* a pneumatically controlled discharge valve for the cabin pressurization system.





Hydraulic power unit for actuating a portion of a control surface in the VC.10, made by Boulton Paul Aircraft Ltd.

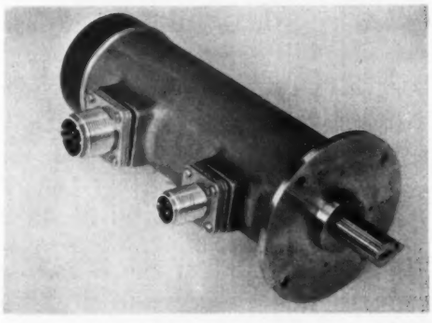


high electrical resistance and retain their chemical properties as well as their resistance to oxidation at temperatures up to 1,250°C. Commercially available in the form of wire, rod, tape, and strip, these materials are used in the aircraft industry for the leading edges of wings and tail-units, air intakes, propellers, and windscreens. By arranging *Brightray* in zig-zag lines or as a heater of mat form, the electrical resistance of each being determined by its position in the area to be heated, any desired surface can be heated. For windscreen heating, fine wires are employed; in one system, such wires of 0.0005 in diameter are imbedded in a plastic interlayer of thin laminated glass. To minimise the danger of reflection, the wires are oxidized to a deep blue colour.

*

The airframe of the BEAGLE B.206 twin-engined executive aircraft, which aroused general interest at Farnborough, is to a large extent bonded with *Redux*, produced by *Ciba (A.R.L.) Ltd., Duxford.* For cases where high temperatures over extended periods are involved, Ciba offers its *Hidux* high-

A wing skin sheet bonded by the *Redux* process (Ciba Ltd).



An ice severity indicator for helicopters (above) and an ice detector for fixed-wing aircraft, both by D. Napier & Son Ltd.

temperature resistant two-element bonding, which is suitable for temperatures up to 150°C, such as encountered in high speed flight. A special bonding film adhesive with a *Hidux* base, suitable for metal-to-metal and honeycomb sandwich bonding can withstand temperatures of up to 200°C in prolonged service, and of up to 300°C for short periods.

*

As a contribution towards giving the helicopter all-weather capability, *D. Napier & Son Ltd., Luton Airport,* has designed an indicator to show the severity of ice on the rotor blades. To achieve effective simulation, the indicator must of necessity be a rotational device. The indicator accordingly consists of a small twin-bladed rotor (see picture), which has a diameter of 14½ inches. The rotor is electrically driven and can move to a certain degree in the direction of the longitudinal axis of the blades. There is provision for alternate heating of the blades. The unheated blade is the one opposite to the direction of out-of-balance of the blades and, as it accumulates ice, it tends to bring the rotor into balance. Further ice build-up takes the rotor to an out-of-balance condition in the opposite direction; thus, the principle of operation is similar to that of a balance. When ice corresponding to a thickness of about 0.312 in on the main rotor blades of a Westland *Wessex* has accumulated on the blade, a microswitch operates the warning or de-icing apparatus. The unit, which weighs 11 lb, can be fitted easily and to practically any helicopter, but must be so placed as to avoid the rotor downwash.

Prototypes of an improved ice detector, the Mk.2, have for some time been subjected to the most severe wind tunnel and flight tests. The unit is designed for fixed wing aircraft and the firm has recently received orders for more than 150 of these detectors, which are to equip the de Havilland *Trident,* Vickers VC.10, and *Transall C.160.* The equipment (see illustration) consists of an electrically-driven cylindrical rotor which revolves adjacent to a fixed cutter (clearance 0.002 in). In service, the rotor is mounted with its axis at right angles to the direction of the local airstream, and any ice forming on the rotor is scraped off as soon as its thickness exceeds the clearance mentioned. The scraping action applies an increased torque to the motor housing; a microswitch sets off the warning device or the main de-icing system. This equipment weighs 2.7 lb, dimensions 8.5 in × 4.125 in × 3.25 in. 5 oz.in. torque is required to operate the microswitch.

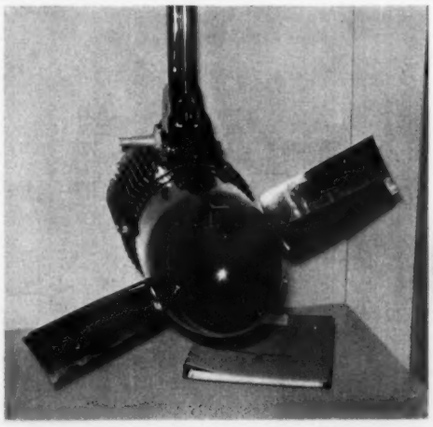
*

The Dowty Group Ltd., Cheltenham, is offering an emergency electrical power supplies unit for airliners, which is to be installed in the de Havilland *Trident* and the Vickers VC.10. The equipment consists of a ram air turbine and a brushless electrical alternator. In the event of main engine failure, the turbine/accessory unit is swung into the airstream, thereby maintaining essential service; it is mounted at the end of a 2 ft arm which is not retractable in flight. The two blades of the ram air turbine have a diameter of 23 in, and the fan is air driven at a nominal 8,000 r.p.m. The turbine weighs 23½ lb, electrical de-icing fitted. The alternator, weighing 95 lb, works in a temperature range of 70°C to −65°C, and has a power output of 15 kVA, a voltage of 208 (3-phase) and a frequency of 400 c.p.s. The unit drives a hydraulic pump, pressure 3,000 p.s.i., which works at temperatures between 70°C and −20°C. The entire hydraulic system when filled (hydraulic oil Skydrol 500A) weighs 51 lb. There is also a two-blade (10-in diameter) military version.

*

A *British Oxygen Co. Ltd., London,* vacuum insulated 75-litre oxygen dispenser was being used to replenish aircraft taking part in the flying display at Farnborough. The mobile dispenser shown here, which was designed to meet Admiralty and RAF specifications, is light and strong. The combination of high vacuum and powder insulant of low thermal conductivity between the two shells keeps evaporation losses at a minimum. The dispenser, controls, and other parts of the unit are mounted on a four-wheel trailer with Ackerman steering and rear-wheel braking.

Ram air turbine and brushless electrical generator (Dowty Group Ltd).

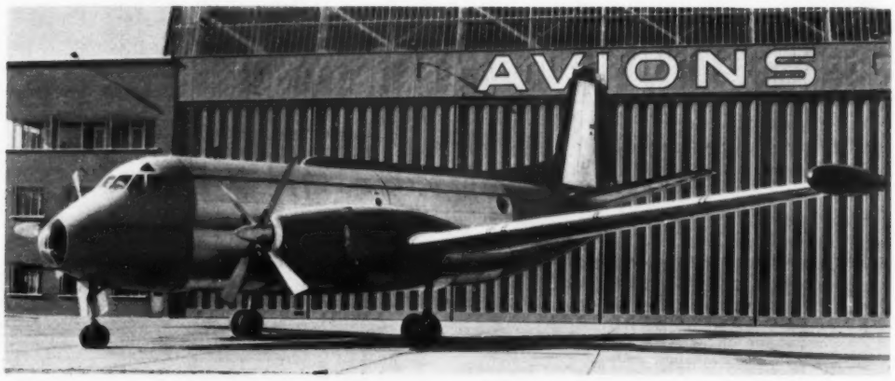


British Oxygen Co. Ltd. manufactures this oxygen dispenser.

What's in the Air?

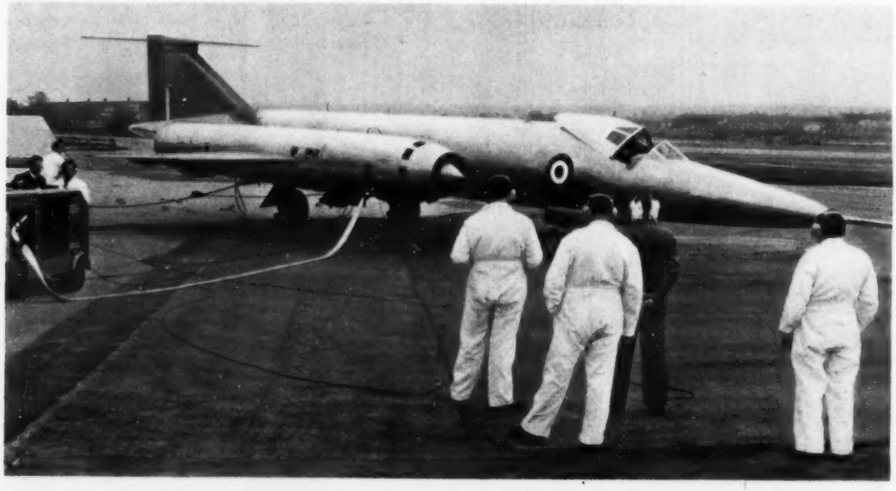
Air Traffic

The Civil Aviation Administration of China (CAAC), a government department under the Ministry of Communications, intends to extend its currently limited international routes. Regular services are planned to Colombo (China and Ceylon signed a reciprocal air traffic agreement some months ago), Moscow, European cities, Japan, Indonesia, the Middle East and possibly West Africa (Ghana). CAAC is at present mainly occupied with the operation of low-fare domestic services and of a good Peking–Shanghai–Canton–Kunming network. The only international services in current operation are from Peking to Ulan Bator (Outer Mongolia), Irkutsk (Soviet Union), Hanoi (North Vietnam-Vietminh), and Rangoon via Mandalay. CAAC has at present an estimated fleet of 50 Ilyushin IL-14s, from 3 to 6 Ilyushin IL-18s, about 20 Li.2s (Russian-built DC-3s) and 40 to 50 Antonov An-2s. The latter are built under Russian licence in a factory in N.E. China, and are used mainly for feeder-line services and agricultural work. CAAC is responsible for all Chinese air services, operating, overhauling and maintaining civil aircraft, airport administration, providing air traffic control and navigational facilities and certification. Operations and Engineering divisions are organised on a regional basis, with the main centre at Peking and three others in Shanghai, Canton and Kunming. Airframe maintenance and overhaul are handled in Peking, whereas line maintenance and routine checks are carried out at the other regional centres. Engine overhaul probably takes place in a factory in the north of the country. In early 1960, CAAC introduced the Ilyushin IL-18s into service on the Peking–Canton route, but withdrew them from regular service some time ago (probably because of technical troubles). They are now being used for special and charter flights. In order to be able to fly the new international routes, CAAC will clearly have to acquire more modern matériel, and there is persistent talk of an imminent order for the British aviation industry.



The Breguet 1150 *Atlantic* NATO ASW reconnaissance aircraft, powered by two Rolls-Royce Tyne 6,000 h.p. turboprops. In addition to Breguet, the following concerns are also involved in manufacturing the *Atlantic:* Association Belge pour l'Avion Patrouilleur, Dornier, Siebel-Werke ATG, Fokker, and Sud-Aviation.

Test run of one of the two de Havilland *Gyron Junior* DGJ.10 jet engines installed in the Bristol T.188 research aircraft. Each of the DGJ.10s delivers 14,000 lb thrust.



Italian-US negotiations on a Los Angeles route for Alitalia were broken off in Rome at the end of September when the two delegations failed to reach agreement on Fifth Freedom traffic. In October, the Italian Government reportedly threatened to renounce the current bilateral air agreement between the two countries unless some agreement was forthcoming. Negotiations on traffic rights for Alitalia's Far East route have been more successful and agreement has been reached with Japan and Thailand for rights at Tokyo and Bangkok. Thai Airways International gets Rome rights for extension of routes to Scandinavia and the US. Japan Air Lines will also get Rome rights.

Air Ceylon and BOAC have signed a cooperation agreement. As from April 1962, Air Ceylon will operate once-weekly Colombo–London and Colombo–Singapore services, using a *Comet 4* on charter from BOAC. The aircraft will fly in Air Ceylon colours, and the service will be operated in pool with BOAC. Any losses Air Ceylon may incur in the first year's operation will be covered by BOAC.

The Government of Trinidad has purchased a 90 percent holding in British West Indian Airways at a reported sale price of £520,000. BOAC is retaining a 10 percent holding as well as one seat on the Board. BWIA's future clearly depends to a large extent on the attitude of the Jamaican Government, which, as is well known, refuses to join the proposed West Indian Federation. BWIA can operate profitably only if an agreement is made for systematic services from Trinidad to the USA via Jamaica. The Company has at present five Vickers *Viscounts* and three Douglas DC-3s.

IATA has published the proceedings and all working papers of the Symposium on Supersonic Air Transport, which took place in Montreal last April. The report on the five-day discussions appears as a 215-page volume. The Symposium working papers are published in a separate volume of 1,200 pages. Copies of the proceedings ($2.50) and working papers ($10.0) are obtainable from

the IATA Technical Secretariat, 1060, University Street, Montreal 3, Canada.

Industry

The TFX project—covering the development of a tactical multi-purpose aircraft complying with the US Air Force and Navy requirements—is again the subject of a tug-of-war between the two services. At first, it appeared that both Air Force and Navy could agree on a common specification, but the picture now looks very different. The two sets of specifications have therefore been issued to the Industry for bids. One of these reflects the Navy's desire for a considerably smaller aircraft than that required by the Air Force. The dictum of Robert McNamara, US Defense Secretary, that the TFX must have trans-ocean performance without refuelling, makes little sense to the Navy with its aircraft carriers. The naval planners are also prepared to sacrifice range and speed in low-level flight for more powerful armament. The Navy considers that the limited range and speed of the TFX could be offset by equipping the aircraft with an advanced missile. The Navy is apparently still pressing for an altered version of the *Eagle* air-to-air missile, which was scrapped earlier this year. Both specifications still retain the principle of variable sweep. The following firms have been invited to submit bids to a committee of two representatives of the US Air Force and one of the Navy by mid-December: Boeing, North American, Grumman, Lockheed, Republic, Ling-Temco-Vought, McDonnell and General Dynamics. The TFX programme will probably cost six to seven thousand million dollars.

Delivery of the first Fiat G.91R/4s to the Greek Air Force at Caselle Airport, Turin. Those present included representatives of NATO, the Italian Ministry of Defence and Fiat, as well as numerous journalists.

General Aldo Remondino *(right)*, Chief of Staff of the Italian Air Force and his predecessor, the late General Silvio Napoli *(left)*. General Napoli died in October, shortly after relinquishing his post on health grounds.

Flying a Northrop T-38 *Talon*, Jacqueline Cochran recently set up a series of new records for women: on August 25th, the record speed of 842.6 m.p.h. over a 15 km closed course; on September 10th, the record speed of 640.392 m.p.h. over a 1,000 km course; on September 15th, the triangular flight Edwards AFB—Kingman—Stoval—Edwards AFB, in which she set up the international record in distance flight on a closed course (class C, Group 1) with a distance of 1,346 miles; on September 18th, the international record for straight line distance flight (Class C, Group 1) with 1,492.394 miles.

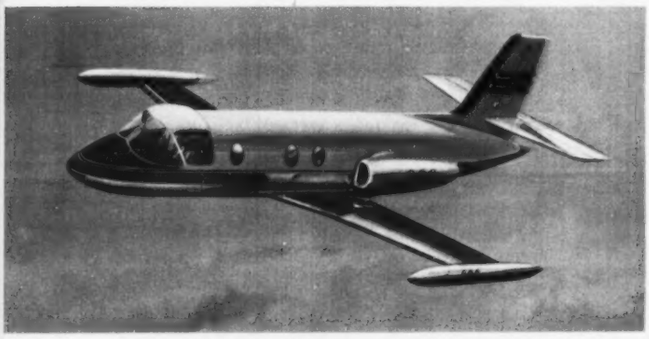
Lockheed Aircraft Corporation is continuing work on the *Hummingbird* VTOL experimental aircraft according to schedule. Two research models of this twin-jet aircraft have moreover been ordered for the Army Transportation Research Command (Fort Eustis, Virginia). Latest available data: powerplant two Pratt & Whitney JT12A-3 turbojets each of about 3,000 lb thrust; empty weight 4,995 lb; equipped weight empty 5,525 lb; max. vertical take-off weight 7,200 lb. Max. level cruise speed 450 kts; rate of climb on two engines (military power) 18,000 f.p.m.; VTOL range with 300 lb payload 290 n.m.; VTOL ferry range 520 n.m.; take-off run for conventional take-off at max. take-off weight of 7,200 lb 1,530 ft; and for conventional take-off over a 50 ft obstacle 2,070 ft. Lockheed also states that the *Hummingbird* will be capable of climbing from sea level to 35,000 ft in three minutes; maximum permissible speed is Mach 0.8. Service ceiling is provisionally estimated at about 40,000 ft.

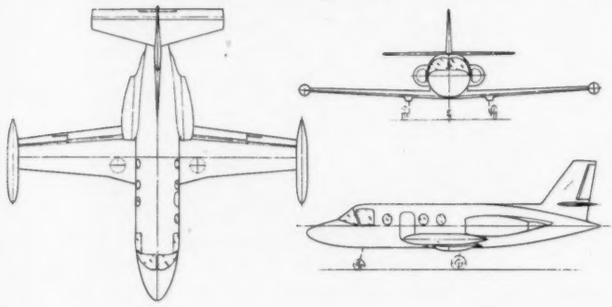
The Royal Navy has decided to acquire three new aircraft carriers, although formal application for necessary financial approval has yet to be made to the Treasury. Construction costs for the three aircraft carriers have been estimated at £180 million. The new carriers will have to be evolved round future naval aircraft which are still at the discussion and research stage. Basic future Fleet Air Arm requirements will be for three types of

Hiller Aircraft Corporation's flying crane project, designated STORC (Self-ferrying Trans-Ocean Rotary-wing Crane). One rotor-blade can be turned through an angle of 180° and locked into position with struts, thus converting the helicopter into a fixed-wing aircraft.

TWA has given Sud-Aviation an order for twenty SE.210 *Caravelle 10A* medium-range jet airliners fitted with two General Electric CJ-805-23C turbofan engines, coupled with an option for 15 more *Caravelle 10As*. The contract was signed in Paris. *Left:* Georges Héreil, Chairman and Managing Director of Sud-Aviation; *Right:* W. L. Trimble, Regional Vice-President, Transportation, TWA.

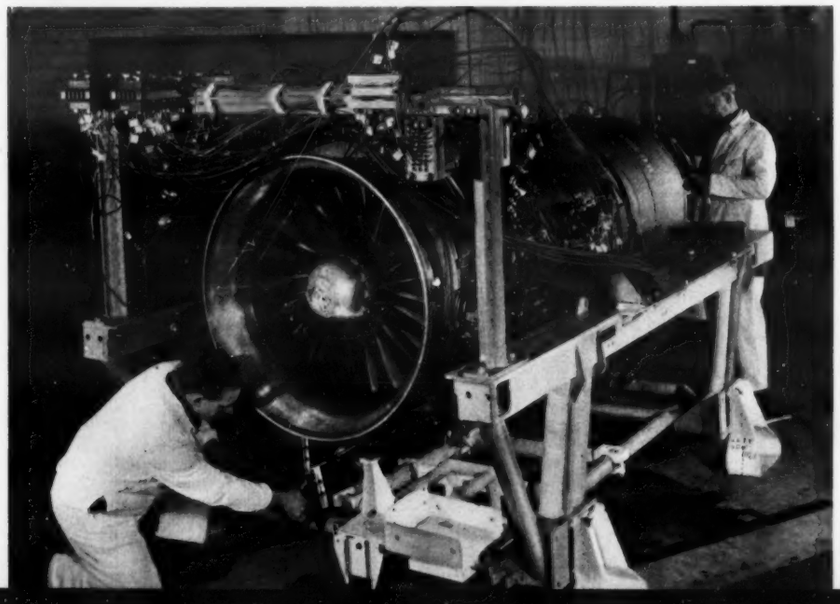
In addition to Bell and Hiller, Hughes Aircraft Company has now submitted the design for a light helicopter to the US Army. Designation: Hughes 369 (US Army designation HO-6). Pictured here is the mockup of this 4-seat turbo-helicopter, which is to be tested in the same way as the Bell 250 and Hiller 1100 designs.





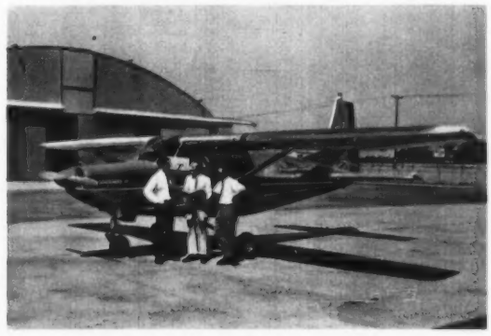
Picture and 3-view drawing of the Piaggio-Douglas PD-808 executive aircraft. The first PD-808 is due to be ready for flight testing at the end of next year. Designed primarily as a seven-seat touring aircraft, PD-808 is also available with cabin layout for up to 10 persons, as a de luxe model for six persons, as a freighter, or as a military trainer. The data published in *Interavia* 8/1961 can now be completed by further details: wing span (with tip tanks) 40.67 ft; wing area 225 sq. ft; capacity of each wing-tip tank 112.5 US gallons; length of fuselage 39.5 ft; maximum take-off weight 15,000 lb; maximum landing weight 14,300 lb; weight empty 7,527 lb, maximum payload 2,000 lb. *Performance with CJ610-1:* take-off speed 142 m.p.h.; take-off distance over 50 ft obstacle 2,770 ft, FAA field length 4,020 ft; maximum cruising speed at 40,000 ft 452 kts; service ceiling 46,700 ft, or 28,900 ft with one turbine; minimum stalling speed 79 kts at maximum landing weight; landing distance over 50 ft obstacle, 2,300 ft; FAA field length 3,860 ft; rate of climb at sea level 7,440 ft/min; maximum flying endurance 4 hours. *Performance with Viper 20:* Take-off distance over 50 ft obstacle 2,960 ft; maximum cruising speed at an altitude of 40,000 ft 460 kts; minimum stalling speed at maximum landing weight 80 kts; landing distance over 50 ft obstacle 2,300 ft; maximum flying endurance 4.2 hours.

A Rolls-Royce RB.163 *Spey* in preparation for a bench run at the Derby altitude test chamber room. The new de Havilland *Trident* and BAC *One-Eleven* jet airliners are powered by *Spey* engines. A military version is under development for the Blackburn *Buccaneer S.2* naval combat aircraft.



aircraft, namely (1) a supersonic low-level strike aircraft to replace the *Buccaneer;* (2) a Mach 2 high rate-of-climb interceptor with advanced air-to-air missiles; (3) an ASW search and strike aircraft.

Some quarters favour the use of swivelling wings to achieve general purpose aircraft to cover all three categories on the lines of the Royal Air Force's concept of a variable geometry basic design for transport, bombing and maritime reconnaissance. The Air Letter's London Correspondent, however, reports that at least two basic types are likely to be needed to fulfil the Fleet Air Arm's requirements, i.e. one aircraft for low-level strike/high-altitude interception, and another for ASW operations. Whilst the Navy is at present committed to helicopters for ASW, it seems probable that, with submarine speeds on the increase, helicopter range will prove insufficient. This means that ASW duties would have to be largely taken over by aircraft.



Alaska Airlines recently took delivery of the first two Lockheed 60 feeder aircraft against its order for five. The aircraft were built by Aeronautica Macchi and flown from Milan to California.

The Navy also has to decide on weapon types to be used—air-to-air, air-to-surface, or air-underwater. Under the present system the government requires maximum cooperation between Naval and RAF specifications. Whether aircraft specifications can be standardized is doubtful, as the Navy has no VTOL requirement, but electronics and weapons specifications could almost certainly be standardized.

Nord-Aviation has built a total of 425 *Noratlas* for service with the French and foreign Air Forces. In Western Germany alone, 161 *Noratlas* have been built, besides the 25 delivered by Nord-Aviation direct to the Federal Government. The total of 425 *Noratlas* is made up as follows: 207 for the French Air Force; 3 for Air Algérie; 44 for export; 161 built under licence in Western Germany; 5 prototypes and pre-series models; and 5 derivatives (one Nord 2507, one Nord 2505, one Nord 2502C and two Nord 2508s).

The SICMAR (Società Italiana Commissionaria Materiale Aeronautica Roma) organization, which has been responsible for negotiating licence production in Italy of British de Havilland aircraft and engines *(Vampire, Venom, Ghost,* etc.), will cease operations on December 31st, 1961, in accordance with its constitution. During the ten years of its existence, SICMAR organized co-operation between Government authorities and the major Italian aircraft manufacturers, to promote the building of the Italian industry after World War II.

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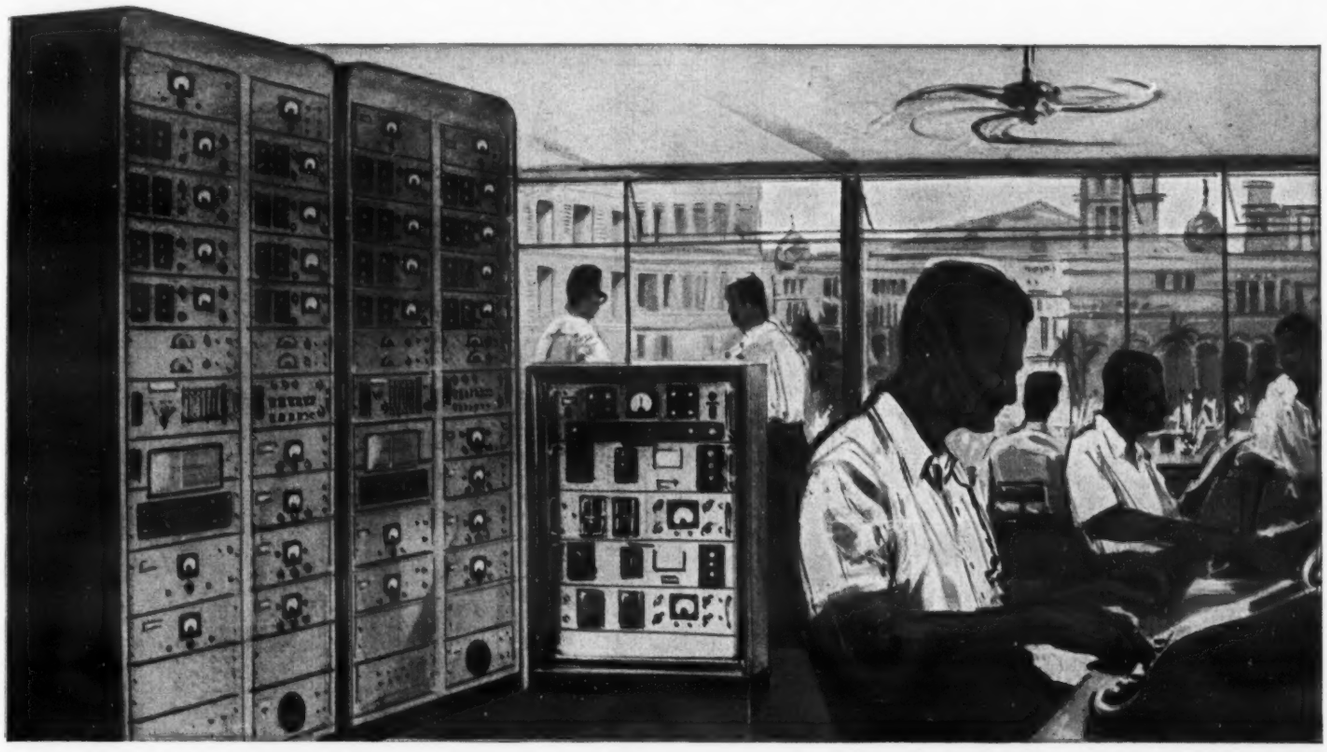

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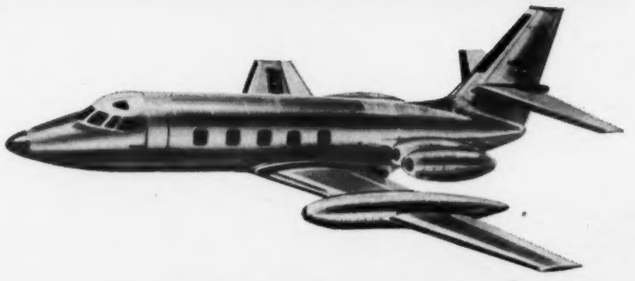

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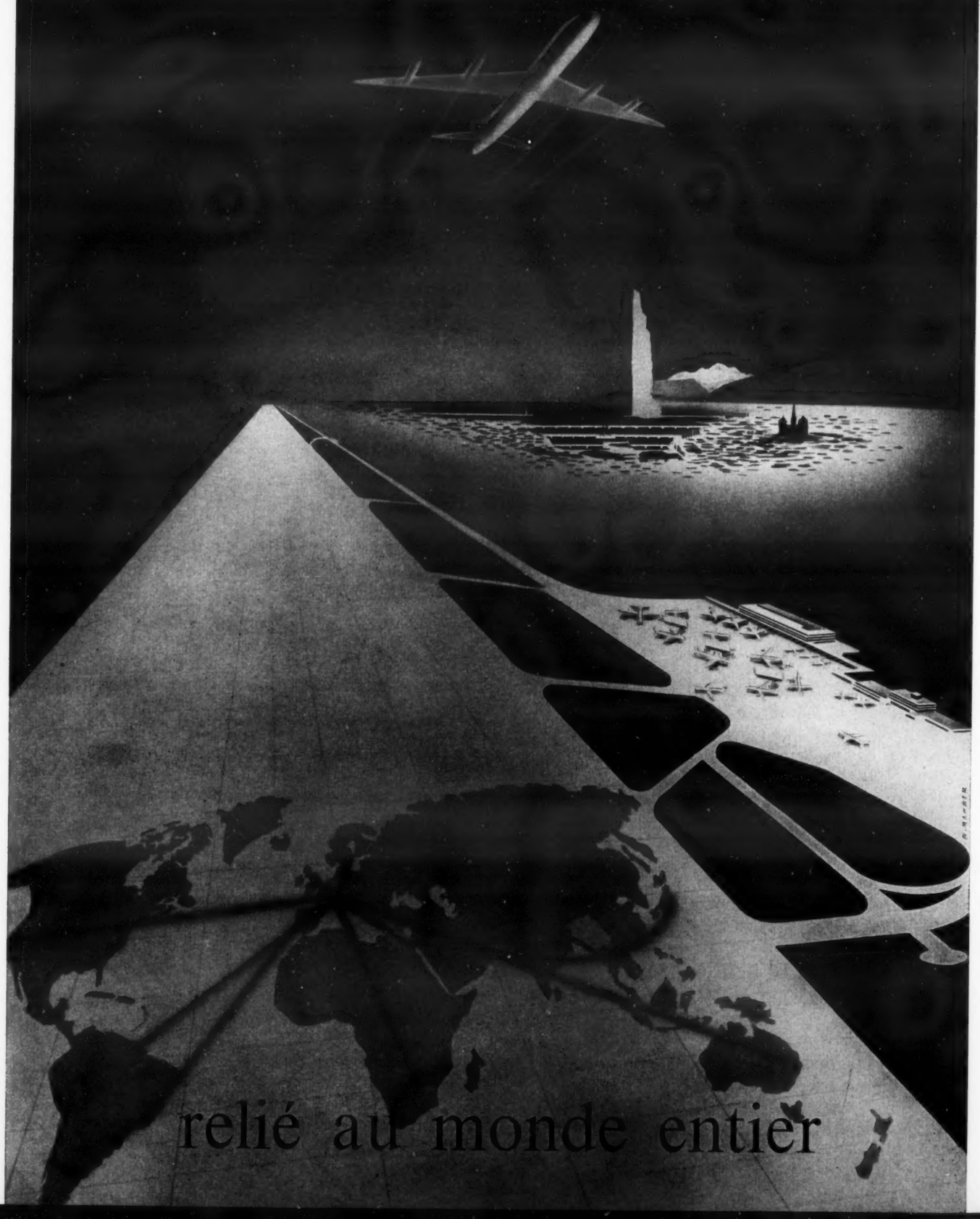

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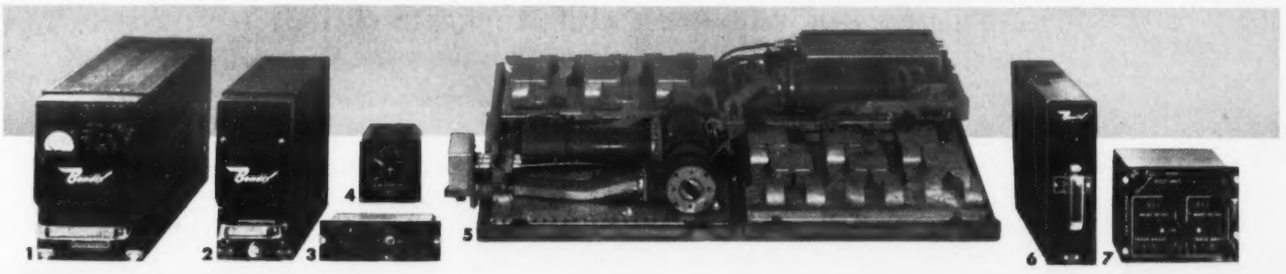

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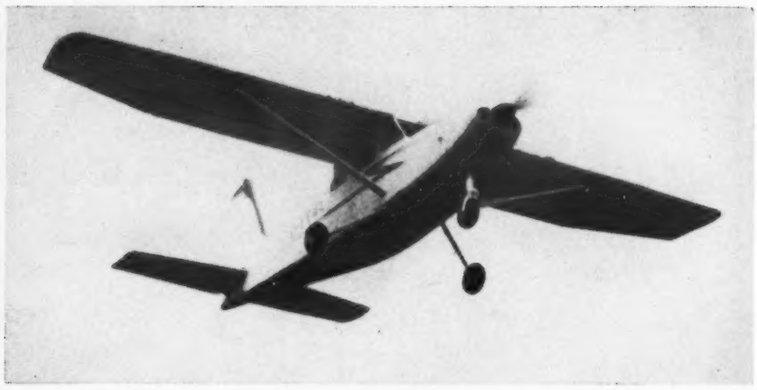

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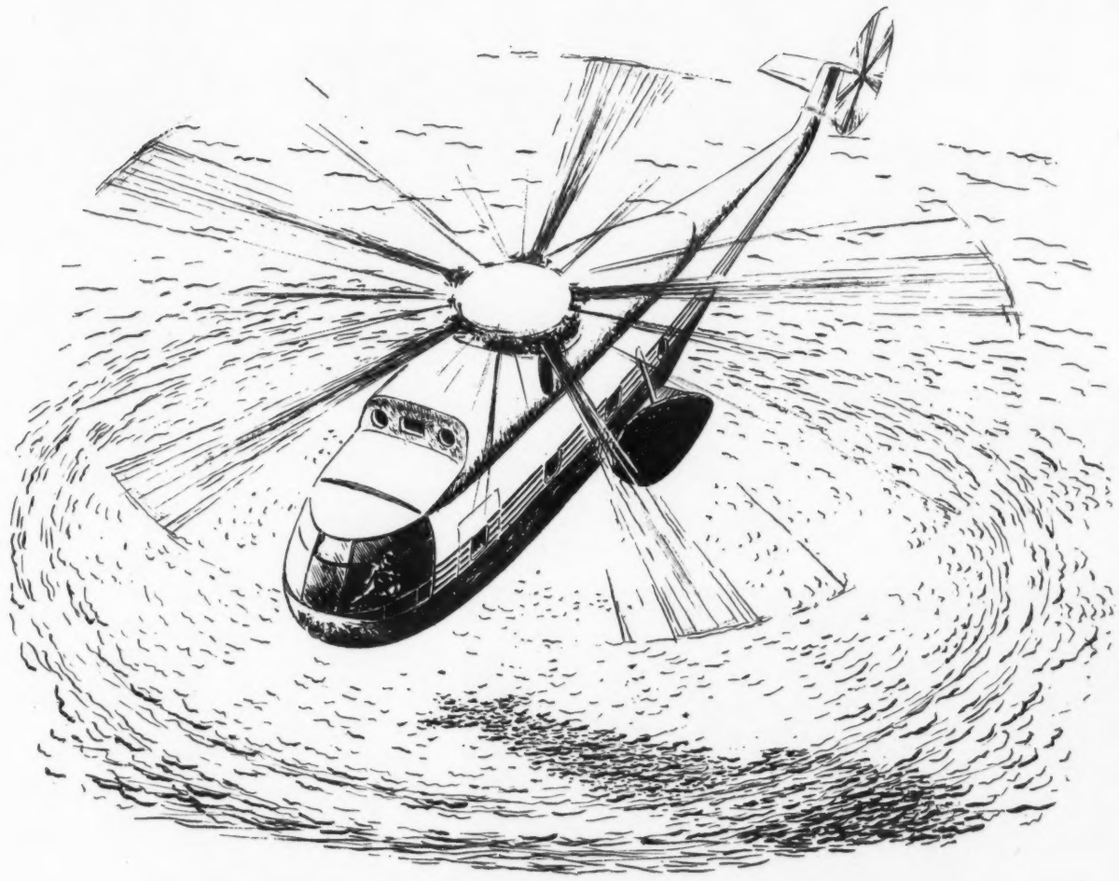

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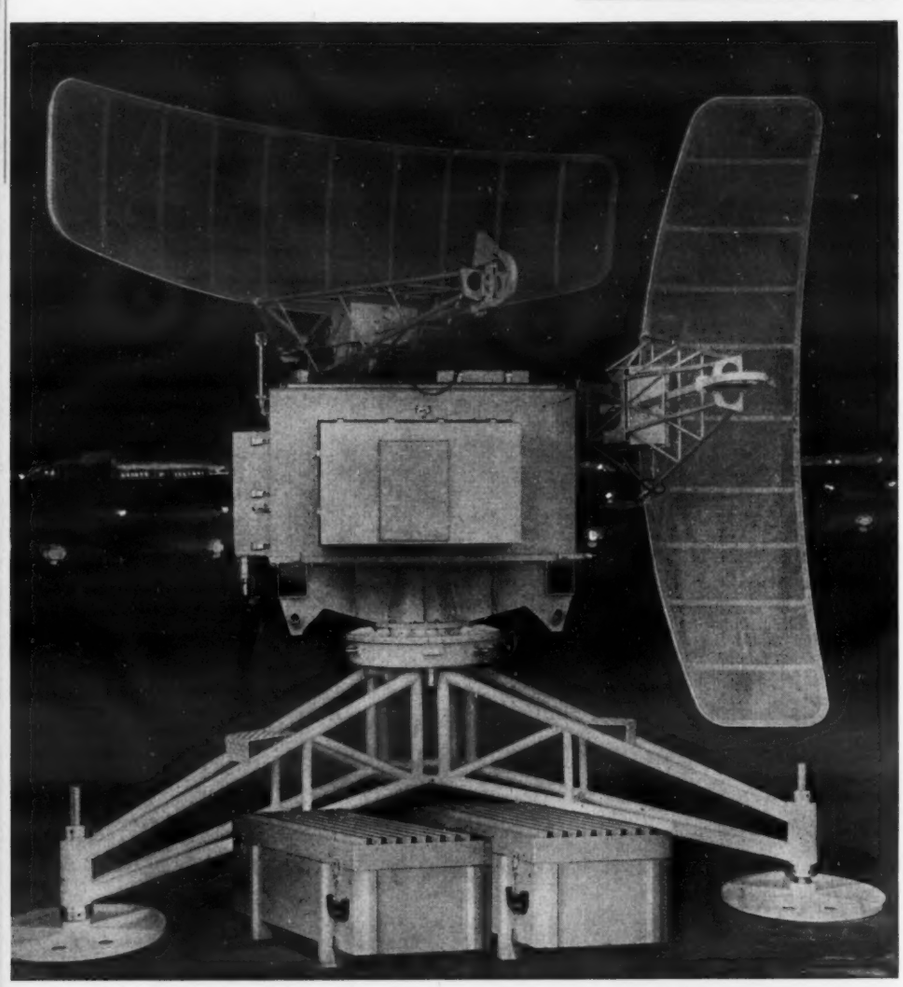

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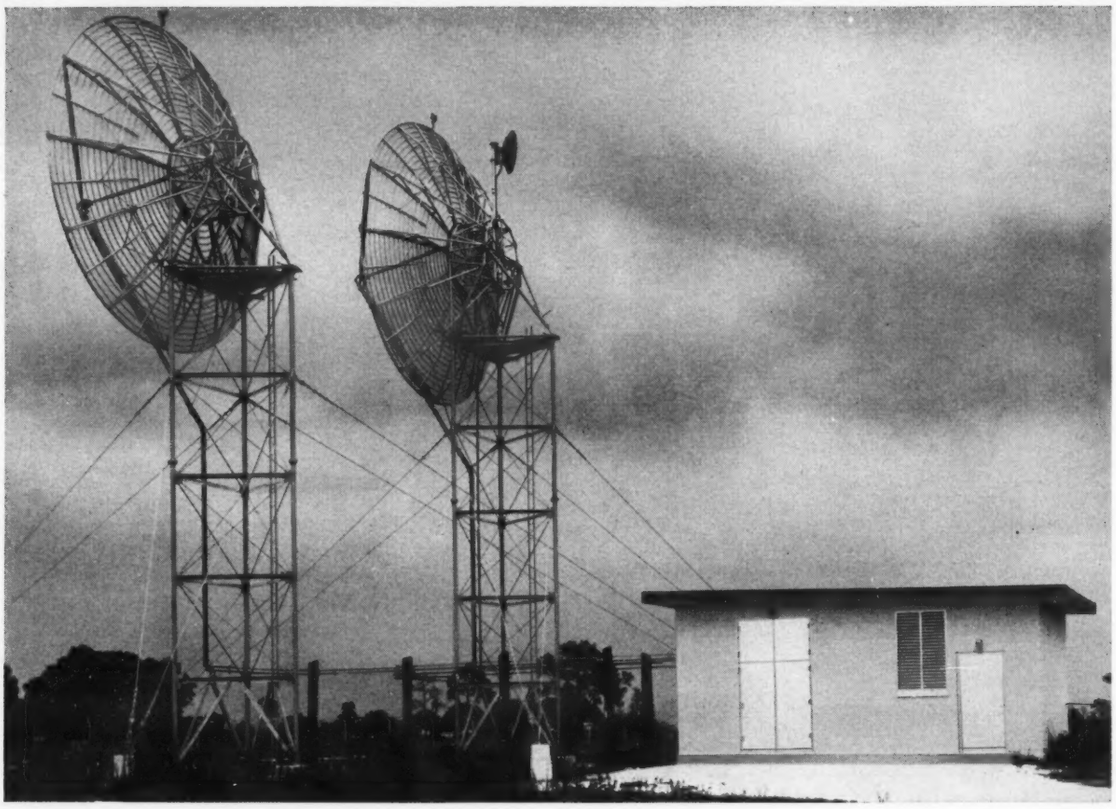

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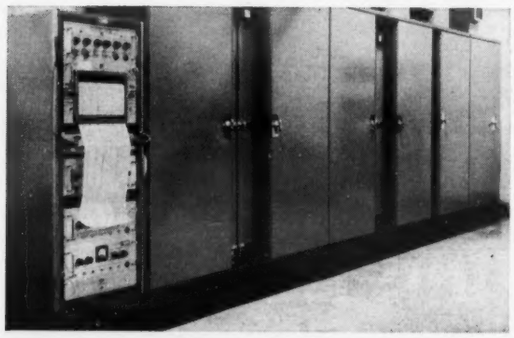

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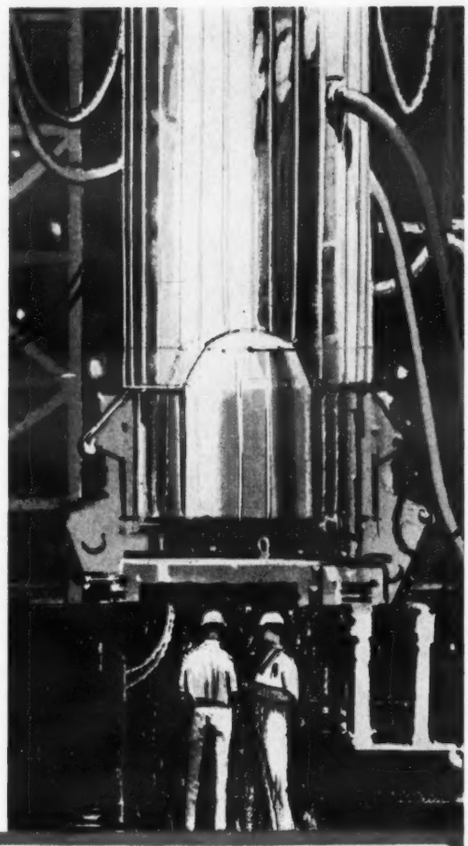

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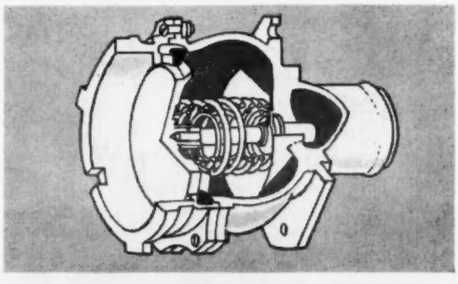

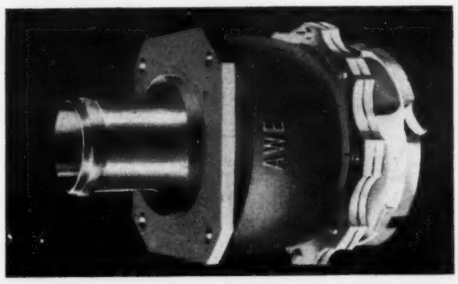

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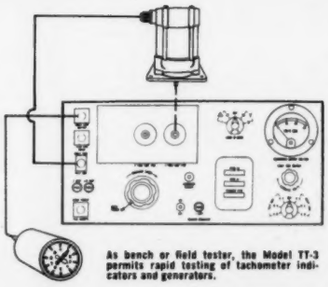
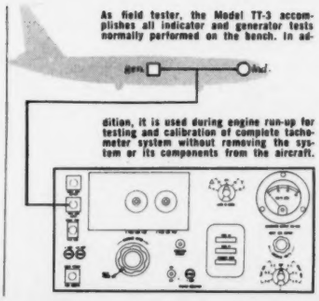


As bench or field tester, the Model TT-3 permits rapid testing of tachometer indicators and generators.



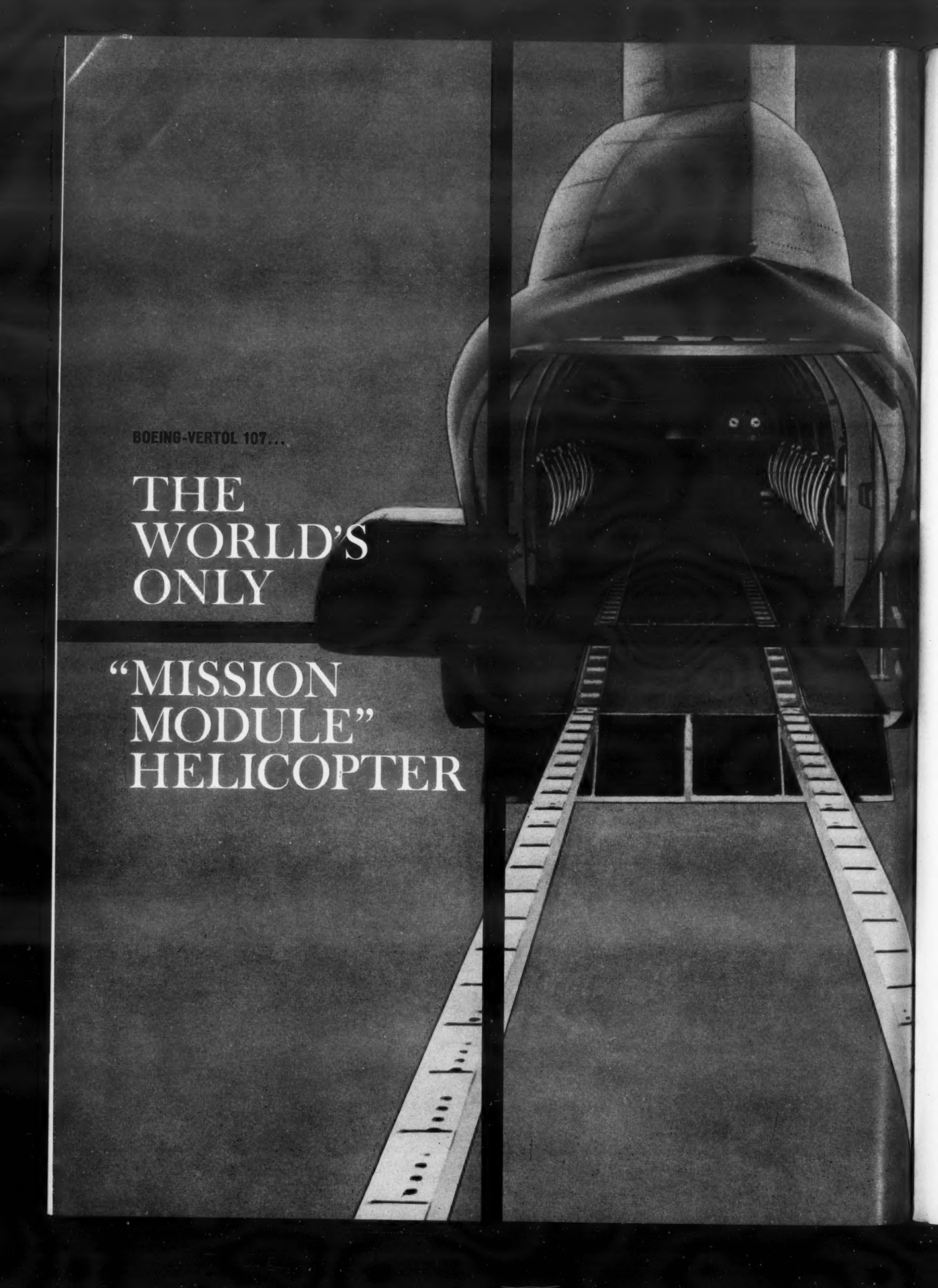
As field tester, the Model TT-3 accomplishes all indicator and generator tests normally performed on the bench. In addition, it is used during engine run-up for testing and calibration of complete tachometer system without removing the system or its components from the aircraft.

"CON-TACH" TT-3

Write today for complete "Con-Tach" TT-3 information. Ask for Engineering Bulletin 202A.

BY Consolidated

AIRBORNE SYSTEMS, INC.
New Hyde Park, L.I., N.Y. • HU 8-1600


BOEING-VERTOL 107...
THE WORLD'S ONLY
"MISSION MODULE" HELICOPTER

BUILT-IN CARGO LOADER PERMITS IMMEDIATE CONVERSION FOR OTHER MISSIONS

" Mission module " design of the new, twin turbine-powered, Boeing-Vertol 107 means this truly versatile helicopter can perform a wide range of military assignments—without costly or time-consuming conversion. A change from cargo mission to minesweeping can be made readily because of basic aircraft design.

In addition, an integrated loading system can be built into this *first* all-mission, all-service helicopter. With the new system one man working alone can unload up to two tons of military cargo in three minutes or less. Even under demanding field conditions, loading can be completed in as little as eight minutes. The fully integrated system makes use of the Boeing Vertol 107's straight-in rear loading ramp. It includes recessed rollers and cargo beams which, when stowed inside the 107, serve as guides for vehicle wheels. A built-in hydraulic winch speeds loading, while the nose-up ground attitude permits fast gravity or taxi unloading. The loading system does not interfere with use of the Boeing Vertol 107 as troop transport, and troop seats can be quickly stowed along the fuselage sides to permit other " mission module " use—for ASW, land or sea rescue, medical air evacuation, missile site support.

The Boeing Vertol 107's capability to perform many missions such as these makes it the logical choice for today's flexible and alert Armed Forces.

VERTOL DIVISION
MORTON PENNSYLVANIA
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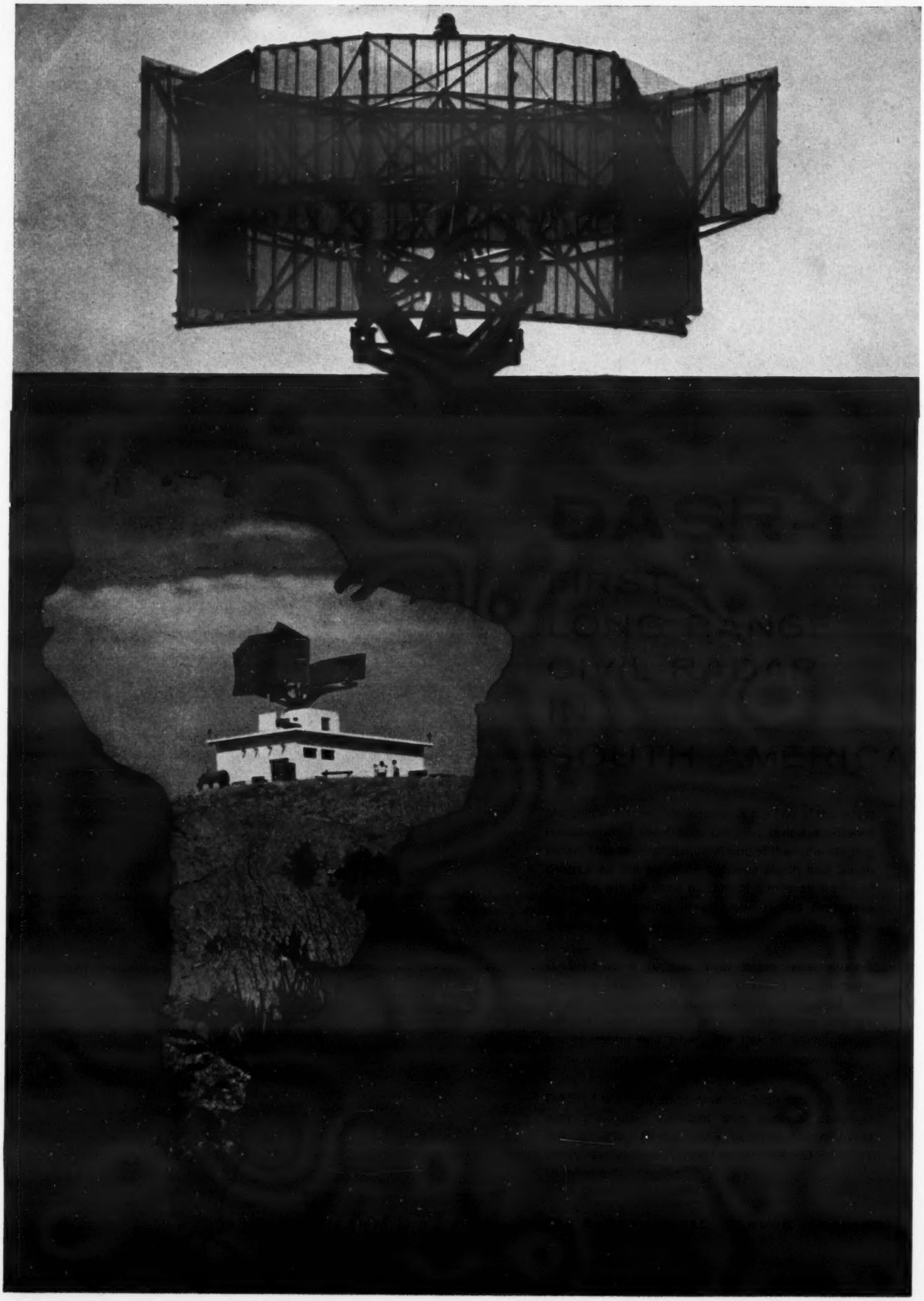


Electronics in Aviation and Industry

The SBAC Show in Retrospect

The slogan for the Electronics Industry's display at Farnborough might well have been "increased reliability." Since the other branches of the aviation industry had nothing sensational in store this time, the untiring effort towards improvement and perfection of electronic equipment was even more conspicuous.

Improved components and their application in modules or in housings screened from environmental effects led to a considerable reduction in liability to failure. The doubling and trebling of automatic regulation and control systems offer a maximum in reliability. The development of miniaturization techniques now permits the production of radio and navigation equipment for sports and executive aircraft, whose safety is consequently enhanced. Nor should we overlook the aviation authorities' endeavours to develop air traffic control and to provide new ATC systems which appear equal to future demands.

The survey contained in the next few pages does not pretend to be exhaustive. Many details have had to be omitted. Nevertheless, from the list of British concerns and their products, one can gauge the importance which electronics has achieved in the whole field of aviation and space. ↠

AIRMEC Ltd., High Wycombe, exhibited a variety of measuring and testing instruments, including the Type 265 frequency meter, the Type 281 VLF phase meter, the Type 201 standard high-frequency signal generator, and the Type 257 VLF signal generator.

Airmed Ltd., Harlow, presented the improved *Airlite 62* headset as well as a small transistorised intermediate lead-amplifier for use with an electromagnetic microphone in place of a carbon-type microphone. Also on show was a portable headset tester, which can test four headsets simultaneously; this is battery-powered, fully transistorised, and weighs under 5 lb.

Amalgamated Wireless (Australasia) Ltd., Sydney, brought a selection of their communications equipment to Farnborough: The CR-6A HF receiver, the HC-5-D HF transceiver for light aircraft (5 crystal-controlled channels, 20-watt output), the VC-10-D VHF transceiver for light aircraft (10 crystal-controlled channels, 1-watt output), and the new VAN-4 airborne DME unit.

Amplivox Ltd., Wembley. The new *Amplilite* headset combines light weight (less than 1 lb), comfort, and robust construction. The new Type 16360 encapsulated miniature amplifier permits substitution of a normal or noise-cancelling magnetic microphone for a carbon microphone. The Type 15050 *Jetlite* headset (weighing less than 7 oz) was especially developed for use in the cabin of low-noise jet aircraft.

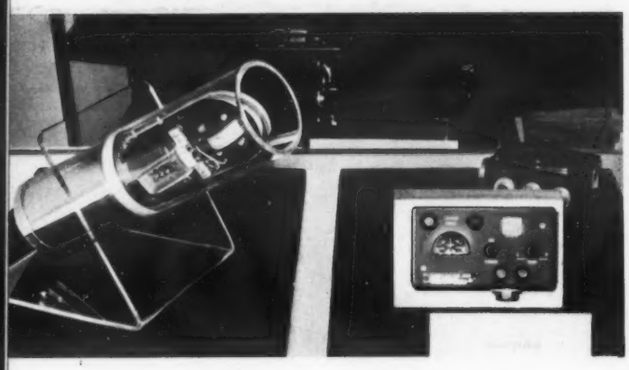
Associated Electrical Industries Ltd., (AEI) London. Transistorised loudspeaking intercommunication equipment, shown for the first time, allows two-way conversations over long distances by the use of normal telephone lines or private land lines. Up to 10 extension units may be connected to the Master loudspeaker. AEI also exhibited controlled rectifiers with a nominal rating of 100 amperes (mean forward current), as well as the type CV 5167 magnetron, with a frequency of 9040/9120 Mc/s (tunable) and a minimum peak power output of 60 kW.

Beme Telecommunications Ltd., London, presented radio control units for target drones and missiles: the X11447 UHF transmitter and the X1792/94 VHF transmitter for remote control of unmanned target

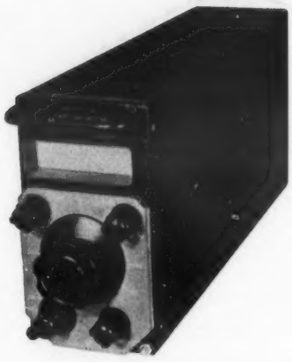
Elliott Brothers (London) Ltd.'s stand, with the VERDAN digital computer on the extreme left.

Multiplexer unit *(left)* and airborne equipment *(centre)* of the Data Transmission system developed by General Electric.

Cossor Radar and Electronics' stand, with models of the CR 353 meteorological radar and the CR 787 mobile panoramic radar in the foreground.



Leader Cable Aircraft Equipment of the Murphy BLEU Blind Landing System.



Ekco Electronics' new Doppler drift unit.

The M.1155 multi-purpose instrument (Southern Instruments) for measuring voltages, frequencies, and time intervals.

aircraft and drones; also the R.9958 general-purpose command receiver and the R.C.60 transistorised general-purpose command receiver for airborne applications in unmanned aircraft and missiles.

Blackburn Electronics Ltd., Brough. The ADONIS (Automatic Digital On-Line Instrumentation System) can process and display any desired number of data, at a maximum rate of 50 values per second. Owing to the use of plug-in modules for the individual units, the system is versatile and highly reliable. The firm also presented the following equipment: the B.I.E. 293 and B.I.E. 294 Hall Effect Multipliers for analogue computers and industrial instrumentation systems; the B.I.E. 2114 and B.I.E. 2116 digital voltmeters (the latter is fully transistorised); the MINILOG digital recorder system for the recording of up to 100 voltages taken from various sources.

British Communications Corporation Ltd., London, has developed a new VHF pack set, the Type 40 (fully transistorised, frequency range 30-174 Mc/s, output 150 mW, weight 2½ lb), a new mobile tunable VHF transmitter/receiver ("Low Band" Model for 80-100 Mc/s, "High Band" Model for 155-176 Mc/s, already available; "Air Band" Model for 118-132 Mc/s available soon; output of all models 10 watts), and a new type 400/100 VHF fixed station (frequency range 30-174 Mc/s, output 15W, weight 118 lb).

Burndept Ltd., Erith. The SARBE (Search and Rescue Beacon Equipment) is a miniature radio beacon which can be attached to a life vest, a pressure suit, or an inflatable lift raft. When the self-erecting aerial is released, the unit automatically transmits a signal on the 243.0 Mc/s International Distress Frequency, which can be detected by search aircraft at a distance of over 70 miles (type BE.241 is a beacon only; type BE.240 is a beacon with two-way speech equipment). Burndept has also developed the lightweight BE.255 VHF transceiver for use in light aircraft.

Canadian Marconi Company, Montreal, presented the CMA-623 Doppler sensor (FM/CW, Janus principle operation, frequency 8800 Mc/s, output 500 mW, height range 50-50,000 ft, speed range 90 to 900 kts). A new feature is the fully transistorised CMA-61 navigation computer, specially designed for the CMA 623 Doppler sensor. For use in small and medium sized aircraft, especially for "bush" operations, CMC has developed the CMA-101/201 HF transmitter/receiver.

Communications (Air) Ltd., Bagshot. The new, fully transistorised FT 17 portable field test set is designed to test the airborne VOR and ILS equipment, and also the VHF transmitter and receiver on the aircraft; the portable FT 11B test set is designed to check airborne VHF communications equipment and marker receiver installations (frequency range 100-156 Mc/s). The company also displayed the type FT 13C VOR/ILS simulator as well as the C.A.2 VOR/ILS aircraft receiving equipment, consisting of three units: the receiver/navigating unit with integral power unit, the controller, and the combined indicator display; the total weight of the equipment is 61 lb.

Cossor Communications Company Ltd., Stanmore. The fully-transistorised CC1 VHF AM pocket receiver (dimensions 6½ in × 4 in × 1 in, weight 15 oz, frequency range 70-100 Mc/s) is suitable for use by airport services, such as police and fire brigades. The CC7 transmitter is a companion to the CC1 receiver; it is fully transistorised and its output is 100 mW.

Cossor Instruments Ltd., London. The newest instrument in a wide range of oscilloscopes is the *Cossorscope* Model 2000, a small portable unit with a double beam cathode-ray tube, in which the entire screen area can be utilised for display. The *Hydraudyne* Model 1063A is a long-persistence oscilloscope, suitable for a variety of applications in the design and maintenance of aircraft and their components. By the use of appropriate transducers, almost any physical force (dynamic and static) can be displayed.

Cossor Radar & Electronics Ltd., Harlow, is at present the only European manufacturer of secondary radar equipment for civil use. The first ground-based installation of this kind (in London) was officially accepted by the British Air Ministry in June of this year. The SR.1251 airborne transponder shown at the company's stand was specially designed for the non-military market; it is 60 percent transistorised and operates on ICAO's double pulse system. Cossor also announced that a later version is available for use with the FAA triple-pulse system, and that the currently available transponder can easily be modified to use the FAA system. In addition, it is possible to modify the SR.1251 transponder to provide automatic selective reply and automatic transmission of flight altitude.

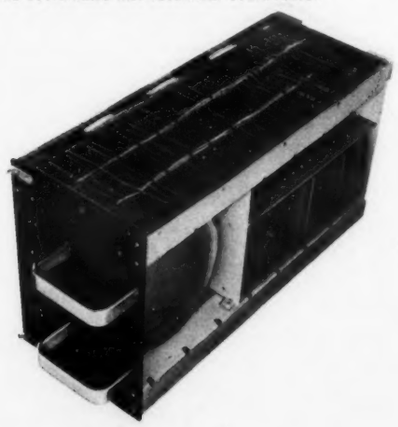
Decca Navigator Company Ltd., London. The new *Omnitrac* airborne digital computer converts the Decca system's hyperbolic coordinates into rectilinear terms, so that the flight log pictorial display can be made on normal undistorted navigation charts. (The new Decca Flight Log Mark 3 should also be mentioned here, as the tracer pen automatically takes up its correct position on the chart selected). The *Omnitrac* computer can also provide a digital indication of range and bearing to any desired point. Thus, the pilot can report his range and bearing to any point, such as a VOR station, on request.

Already in series production, the roller map device provides a continuous position indication on a standard aeronautical chart. A selected map strip advances under an aircraft symbol on a transparent strip which can move in a transverse direction. Two different versions of the roller map are offered: type 9073 requires manual setting of the ground speed and the "across track" index, whilst type 9268 accepts inputs from either Doppler or inertial navigators, and the map and symbol strips move automatically.

The type 61 Doppler navigation system should also be mentioned; it is available either with a display conforming to ARINC specifications, or as part of a DIAN (Decca Integrated Airborne Navigator) system, with presentation on the Decca Flight Log.

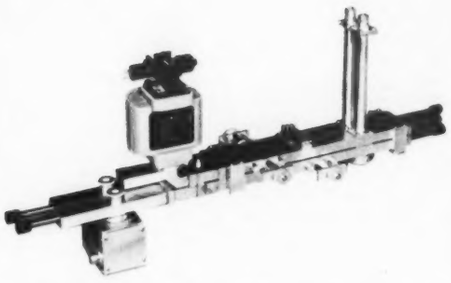
Decca Radar Ltd., London. The production version of the TDS Mark V (Transistor Display and Data Handling System) shown at Farnborough received considerable attention. By enclosing the transistor circuits in a sealed housing, inside which air temperature and humidity are maintained constant within very narrow limits, it is possible to attain a high degree of accuracy and reliability. During service tests of over 10,000 hours, availability reached 99.8 percent. The TDS Mark V can process data from a multiple radar

Decca Navigator's *Omnitrac* Computer, for converting hyperbolic coordinates into rectilinear coordinates.



Stand of Honeywell Controls, with ground test equipment for the McDonnell F-101.

Thermionic's Series IV Magnetic Tape Recorder.



Test model of the Marconi diode parametric amplifier and mixer.

Antenna system of Standard Telephone & Cables' Doppler wide aperture direction-finder DDF-1. The shape and array of the rotating dipole antennae are easily recognizable.

installations as well as the output from digital computers, and can supply a maximum of 20 display units. The screen can simultaneously depict the information from raw and synthetic radar displays, together with the *Interscan* symbols created by TDS itself, and alpha-numeric symbols.

This manufacturer also announced two new weather radars. The type 43 weather radar (3 cm wavelength, peak pulse power 75 kW) presents a range height indication in addition to the PPI display, enabling a close study to be made of the vertical structure of the precipitation area. Type 44 (10 cm wavelength, peak pulse power 750 kW) uses a longer wavelength to secure better penetration through heavy and widespread precipitation. For the WF 2 weather radar, Decca has developed an automatic data printer, which continuously prints on an electric typewriter the elapsed time, range, azimuth and elevation of the target. There is also the *Radargraph* automatic printer for recording radar information, which provides an accurate and continuous visual record of the PPI display. The *Radargraph* is suitable for use in any of the Decca weather radar systems.

Ekco Electronics Ltd., Southend. Two smaller and lighter scanners (either 18 in or 12 in diameter) are now available for the E190 airborne radar, so that the weight of the overall installation can be reduced from 60 lb down to 46 lb. A new Doppler drift unit, which indicates drift angle, is now available to complement the E190 radar. Ekco also presented a range of transistorised static inverters, including the Type E210 single-phase inverter (55v or 115v, 400 c/s A.C. output from 24v D.C. input).

Elliott Brothers (London) Ltd., London, is currently engaged in development work on the Elliott 502 digital computer, under a British Air Ministry contract, which will lead to the development in about two years time of an automatic air traffic control system. Since it will take several years to bring such a system to the operational stage, Elliott proposes the use of the general-purpose 803 digital computer as an interim solution. At Farnborough, Elliott demonstrated the versatility of this computer in five functions: automated seat reservations, automatic communication switching, automatic control of a fighter interception mission, simulation of aircraft movements on a PPI scope for air traffic control training, and automatic processing of flight plan data, including monitoring of position reports and predicting of potential conflicts.

In keeping with the motto "automation from take-off to touch-down," Elliott presented an impressive range of airborne equipment and systems. The VERDAN airborne digital computer (Autonetics Division, North American Aviation Corp. licence) has about the same capacity as the 803 computer, but occupies much less space (1½ cu ft) and weights only 82 lb. In the development of the automated flight control system for the Vickers VC.10, every effort is being made to ensure maximum reliability in automatic landing. During the approach and landing phases, both of the system's autopilots operate in parallel, although only one of these at a time maintains control authority. A fully automatic change-over facility ensures immediate take-over by the second unit in case of malfunction of the responsible autopilot, without any interruption whatsoever. For executive aircraft, Elliott offers lightweight VHF communication equipment whose performance almost equals that of much larger sets (720 channels in the 108-144 Mc/s range, spaced at 50 kc/s, output 12 watts, weight 8.5 lb including modulator-power unit). In conclusion, it should be mentioned that Elliott is presently working on the development of a high-precision microwave course beacon for the BLEU Blind Landing System.

English Electric Aviation Ltd., Stevenage exhibited the new PIM (Precision Indicator of the Meridian), which uses a rate gyroscope to determine true North, and is suitable for the orientation of missiles and artillery, for surveying, and many other applications. Within 15 minutes of setting up the equipment, the direction of true North can be determined with an accuracy of one minute of arc.

The Fairey Company Ltd., London, exhibited a microwave reflector for the *Jindivik* target aircraft. The round reflector (10 in diameter) considerably enhances the strength of the radar signals reflected from the *Jindivik* (25 ft 8 in span), so that on the radar scope it

MIDAS playback equipment by Royston.

English Electric's North-finding PIM gyro apparatus.

Redifon Ltd.'s stand. *Right:* the *Redifax* installation for transmitting facsimiles of weather charts. *Extreme left:* the latest *Radic* analogue/digital computer.

British Communications Corporation's fully-transistorised V.H.F. Packset.

appears to be an aircraft with a wing span of about 65 ft.

Ferranti Ltd., Edinburgh, exhibited a selection of well-known equipments such as the AIRPASS I fire control system and the improved AIRPASS II navigation and fire control system; the ISIS fire control system (Integrated Strike and Interceptor System); an aircraft angle-of-attack indicator; a number of accelerometers, gyroscopic instruments (shown for the first time: the type 100 gyroscopically-stabilized platform for aircraft navigation systems), rectifiers, precision potentiometers, etc.

Ferranti presented a newly-developed transistorised audio warning device which transmits a speech warnning to the pilot when malfunctions or failures occur (for example, low oil pressure). This warning is relayed through the pilot's normal radio communications head set. The appropriate messages (normally of 3 seconds duration) are recorded on the 15 tracks of a closed loop of magnetic tape about 9 inches long.

Access time for a warning is about 1/4 second. Another new item was the "Moving Map Display" developed in conjunction with the RAE, a device for the pictorial presentation of navigation data. Aeronautical charts are optically projected onto a 6 in diameter viewing screen. The aircraft's position is denoted by a fixed symbol, under which the map advances. The maps are projected from 35 mm colour film strips, and each map covers a ground area of 120 n.m. by 170 n.m.

One of the most important projects on which Ferranti Ltd. is working is the Apollo computer, the installation in the Southern Air Traffic Control Centre at Prestwick being completed a few weeks ago. This computer will be used in experimental development and testing of data processing systems for air traffic control over the North Atlantic.

Flight Refuelling Ltd., Tarrant Rushton Airfield, demonstrated the control system for the *Meteor U Mk.16* pilotless target aircraft. In flight an autopilot controls the aircraft, in response to radio commands. The radio commands consist of a combination of two low-frequency tones which frequency-modulate a 70 to 80 Mc/s carrier. The signal is demodulated aboard the aircraft and is led to eight filter circuits, each of which accepts an individual tone.

The General Electric Co. Ltd., Coventry, has developed a digital data-transmission system for air traffic control. The experimental model shown at Farnborough is fully transistorised and provides a ground-to-air digital data link. This data is converted into analogue form in the aircraft and can either be displayed by instruments or fed directly to the autopilot. For ground transmission over long distances, three normal telephone circuits suffice to carry the digital data, as multiplex techniques are used.

General Precision Systems Ltd., Aylesbury, already has a substantial number of orders in hand for its *Terravision* visual flight simulator, which provides a visual picture of the outside scene during simulated take-offs and landings. The airport and its vicinity are realistically depicted on a 1:2,000 scale roller belt model which moves in front of a camera. The latter can move in two planes, and the image viewed by the camera is either projected on a wall screen outside the simulator cockpit or displayed on television screens which are built-in around the cockpit instead of windows. The equipment can simulate cloud base heights from 0 to 1,000 ft and visibilities varying from 300 yards to 4½ nautical miles. GPS has also developed an electronic radio aids unit for use in existing simulators, which simulates and displays signals from navigation facilities such as VOR, ILS, and NDB on the appropriate cockpit instruments.

Halpins of Hampshire Ltd., Southampton, has developed the ADAS (Aircraft Directional Accuracy System), an airborne navigation system consisting of an MF receiver (combined with a VOR control unit), a VOR/ILS receiver, a combined MF/VOR aerial, and a combined cathode ray tube indicator. The system features light weight and high accuracy, and is suitable for use in touring and executive aircraft.

Honeywell Controls Ltd., Greenford, presented at Farnborough an Automatic Systems Analyser for the testing of the McDonnell F-101 systems. The equipment is automatically programmed by a punched tape and it will check all the aircraft systems with considerable savings in time and personnel.

Marconi Instruments Ltd., St. Albans. This firm's wide range of products includes measuring and testing equipment covering the VLF to SHF range. A variety of items were on display, such as signal generators, bridges, oscillators, oscilloscopes, voltmeters, watt meters, and pulse generators.

Marconi's Wireless Telegraph Co. Ltd., Chelmsford, exhibited at Farnborough the SD.1016 Tabular Data Display Unit, as well as the new SD.1015 radar console, which simultaneously displays both raw radar signals and synthetically produced information on the screen (see *Interavia* 9/1961). Another new development by Marconi was also on display: an experimental solid-state parametric amplifier and mixer using semi-conductor diodes, which can be used in satellite or tropospheric scatter communications or in radar installations, to provide much greater low-noise amplification than has hitherto been possible. In tests conducted with an SD.100 radar transmitter/receiver, the use of the new amplifier/mixer resulted in an equivalent transmitter power increase from 0.5 megawatt to 1.75 megawatts. Other equipment designed by Marconi includes the "Sixty Series" of aircraft radio units. This range includes the 6400 VHF transmitter, 6401 VHF receiver, 6402 navigation unit, 6404 glide slope receiver, 6403 marker receiver, 6407 ADF receiver, 6409 controller, and 6410 ADF loop antenna.

Murphy Radio Ltd., Welwyn Garden City, exhibited the airborne leader cable equipment for the BLEU Blind Landing System, and the test equipment for this installation. The Murphy Radio Ltd. production programme also includes the ground leader cable equipment for the BLEU system as well as various types of radio equipment and navigation aids.

Louis Newmark Ltd., New Addington, is the only British manufacturer of autopilots for helicopters. A three-axis automatic control and stabilization unit of this type was on view at the firm's stand.

The Plessey Co. Ltd., Ilford. Among the many items of aircraft electrical and mechanical equipment and components exhibited by Plessey, the latest development in the field of radio communications is an HF linear transmitter amplifer with an output of 1 kW. The amplifier is continuously adjustable over the frequency range 1.6 Mc/s—27.5 Mc/s. For RAE testing and development of long-range navigation systems, Plessey has developed a VLF receiver which has already been mounted aboard a *Comet 2E* for research on the propagation characteristics of myriameter waves (VLF waves, over 10 km in length).

Pye Ltd., Cambridge, gave a broad presentation of its wide-ranging production programme in the domain of fixed and mobile telecommunications systems and airborne equipments. Pye's Instrument Landing System was a focus of attention; to date, it has been installed at over 130 airports in 18 countries, and it plays an important role in the BLEU Blind Landing System of the RAE (Bedford).

Rank Cintel Ltd., Lower Sydenham, presented three new items of equipment. The PEEP (Pilot's Electronic Eye-Level Presentation) displays all essential flight data such as attitude, altitude, and speed directly in the pilot's line of vision (see *Interavia* 9/1961). The tri-colour cathode ray tube of the "central warning system" is designed for integral mounting on an aircraft's instrument panel, and it provides a "written" warning in cases of abnormal performance or failure. The rectangular image screen (4 in wide by 10 in high) is divided into three equal segments, whose colour-coded indications denote the urgency of the warning: the red zone shows malfunctions, the amber zone indicates warnings, and the green zone is used for routine checks.

Corsair, designed at the Royal Aircraft Establishment, Farnborough, is an all-transistor digital differential analyser. The computer, like an analogue device, has a number of integrator units, but the computation within these is performed digitally. The *Corsair* thus possesses the adaptability of a general-purpose digital computer, while retaining the analogue computer's directness of application.

Redifon Ltd., London. The firm displayed the following new equipment: the transistorised GR 410 HF-SSB radio telephone; the A.43R VHF pack set; the G.423R HF-SSB transmitter; the *Redifax* facsimile equipment for copying written material, documents, weather charts, etc. At their stand, Redifon also demonstrated the latest *Radic*, an analogue digital computer for educational and research applications.

Royston Industries Ltd., Byfleet, has already booked a number of orders for its MIDAS flight data recorder. It has a tape speed of 1/10 inch per second, which allows a maximum recording duration of 60 hours. The ½-inch wide tape can simultaneously record up to 270 different parameters. The associated playback machine operates one hundred times faster than the recorder, and allows simultaneous examination of all the recorded data. The playback can be presented either in the form of a printed record for quick check or on a multiple trace record, if a more

Decca Radar's TDS Mark V transistorised radar data display system. *Bottom right:* cooling equipment; *top left:* an open cabinet with three drawers of interchangeable circuit cards.

Transistorised AC rectifiers for 1,500 VA power (by Westinghouse).

Moving Map Display by Ferranti.

detailed analysis is required. In addition, the latter data record can be fed directly to an analogue computer or, after suitable conversion, to a digital computer. The *Law Simulator* is a new ancillary equipment by Royston, which constantly compares the recorded data with the normal operation values, and actuates a "level-gate" signal whenever the former exceed predetermined tolerance limits.

The all-transistor VHG recorder is a new development, for recording speeds, altitudes, etc. particularly for fatigue investigations (6 channels for continuous recording, and an additional channel for multiplex recording, tape speed ½ inch per second, 60-hour recording duration).

Short Brothers & Harland Ltd., Belfast, displayed the new SC.5 simulator, which was designed to test and modify the Short *Belfast* autopilot system. A newly developed automatic power control for the lift-jet engines of VTOL aircraft also evoked interest. During the transition phase it compensates for any vertical accelerations occasioned by gusts.

Smiths Aviation Division, Wembley, presented the new SEP.5 multiplex autopilot, which will be used in a duplex installation in the de Havilland *Trident* and in a triplex installation (for fully automatic blind landing) in the Short *Belfast*. Smiths also showed a precision altimeter, which has been selected for the Vickers VC.10, and an airspeed indicator which will be secondary equipment in the *Trident* and primary equipment in the VC.10. The latest development of the PVD (Para-Visual Director) system attracted special attention; it is currently undergoing long-term trials with several airlines and air forces.

The Solartron Electronic Group Ltd., Farnborough. In addition to the recently announced all-transistor radar simulator (*Interavia* 9/1961) Solartron brought out several other new developments: CD.1015 general-purpose oscilloscope; CT.436 double-beam oscilloscope; GO.1005 pulse generator; DO.1001 crystal-controlled signal generator; ED.1035 and ED.1036 high-speed printers, the latter with a register to store information from data-processing equipment. The L.W.1080 magnetic tape recorder/player is portable, low in cost, and of instrumentation quality (fully transistorised, up to 16 tracks, FM or direct operation, 6 tape speeds from 60 in/sec down to 1⅞ in/sec, weight 185 lb).

Southern Instruments Ltd., Camberley. Among the numerous items of test and measurement equipment offered by this firm is the new M.1155 general purpose digital voltmeter-frequency meter-time interval meter. Another new development is the M.1225 cathode follower, wich amplifies signals from piezo-electric transducers, to allow their transmission over considerable distances to appropriate measuring equipment.

At the same stand, Storno-Southern Ltd. was exhibiting a wide range of radio communication equipment: CQF 13C-12 mobile VHF radiotelephone, CQF 31 fixed VHF R/T, and CQF 63 UHF link for controlling remote VHF stations and for telemetry.

Sperry Gyroscope Co. Ltd., Brentford, presented the SP-3 light-weight autopilot, a 3-axis unit weighing only 27 lb, which will be fitted in the BEAGLE B.206 and in the Short SC.7 *Skyvan*. The Company also showed the recently introduced CL.6 *Gyrosyn* compass and a twin gyro platform, as well as the VGL.2 vertical gyro equipment for the *Trident*.

Standard Telephones and Cables Ltd., London. The new DDF.1 wide-aperture Doppler direction-finder was set up and made ready for demonstration at short notice for the Show. This installation features accuracy, reliability, and low cost; it is especially suitable for small and medium-size airports. Two VHF dipoles are mounted on the ends of the 12-ft aerial support arm, which rotates three times per second. The radio receiver is housed in a weather-proof cabinet below the antenna, so that only the electromechanical bearing indicator need be installed in the control tower. Bearings are determined to ½° accuracy, with a response time of only 1 second. In developing this unit, STC laid stress on simplicity and ease of maintenance. A further advantage of the DDF.1, which was emphasized, is that site selection is much simpler than for direction finders previously available.

The STC-developed type STR.37 VHF transmitter/receiver, for use in touring or executive aircraft, attracted much notice at Farnborough; it is fully transistorised (400 channels at 50 Kc/s spacing in the 116-135.9 Mc/s range, 200 mW output, which can be increased to 6 or 25 W with amplifiers, weight 6½ lb). Presently under development is a matching independent radio navigation system made up of three units. Other interesting exhibits at the STC stand were a model of the newest type of VOR ground beacon (50 or 200 W output) and an animated display showing how the STANTEC automated reservations system operates.

Thermionic Products (Electronics) Ltd., Southampton. The new transistorised Series IV magnetic-tape recorder can be advantageously used wherever it would be uneconomical to set up the much larger Series III equipment. Its six-channel tape has a speed of 15/16ths in/sec and provides 8 hours of recording. The Series III recorders provide up to 20 tracks, with a tape speed of 1⅞ in per second and a maximum recording time of 12 hours. The type D 2069 eight-speed recorder for digital applications is another new product.

Thorn Electrical Industries Ltd., Enfield, exhibited a wide selection of electrical and electronic devices and components for aircraft and ground installations, including connectors, miniature lampholders, navigation lamps, electroluminescent panel signs, and neon indicator lamps. The latest development is the *Plasteck* instrument panel edge-lighting system, which will be used in the Vickers VC.10, the de Havilland *Trident* and the Short *Belfast*.

Ultra Electronics Ltd., London, has developed an all-transistor miniature radio beacon (series 2A7) for sea rescue operations. The device automatically transmits a tone on the 243 Mc/s international distress frequency, and is optionally available with a two-way speech facility. The beacon range is 60 n.m. while speech range is over 10 n.m. Another new item is the 3A2 radio paging system, which allows selective calling of up to 100 individuals, and has a maximum range of 5 miles.

Westinghouse Brake and Signal Co. Ltd., London presented a number of semi-conductor elements, such as rectifiers (copper-oxide, germanium, selenium, silicon), high-power transistors, and controlled silicon rectifiers and their applications in such equipment as a 1.3 kVA A.C. power regulator and a transistorised 1500 VA rectifier.

W.S. Electronics Ltd., London, presented a selection of their radio communications sets, including the D.103 emergency transmitter/receiver; the D.303 emergency R/T for use up to 60,000 ft altitudes; the D.120A (UHF) light-weight airborne transmitter/receiver with D.128 homing adaptor; and the D.145 airborne VHF telemetry transmitter.

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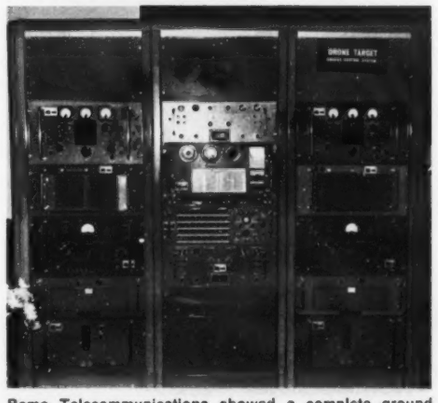
With the theme "Safety in Aviation", the British **Ministry of Aviation (MoA)** gave a summary of the state of air traffic control and the scheme for future ATC systems. Models were used to illustrate the airways system of the United Kingdom, as well as the low-level and high-level radar coverage at present provided over the country which is, before long, to be extended over Britain's entire airspace. The MoA's most important projects in the air traffic control field have already been mentioned in another place in this survey. The Ferranti *Apollo* computer, recently installed at Prestwick—and the Elliott 502 computer ordered for London with delivery in about two years' time—should serve as the basis for exhaustive tests for the development of automated data processing and checking systems.

In its own marquee in the Radar Park, the ATCEU (Air Traffic Control Experimental Unit) of the British Ministry of Aviation gave an impressive demonstration of its *modus operandi*. The main task of this research and experimental unit is first to define exactly the problems which arise in practice and then to find the solution. For this purpose, the ATCEU has developed an air traffic simulator for 15 "aircraft," giving representation of all conceivable traffic situations, both on radar screens and on conventional control consoles. By means of this simulator, existing procedures can be examined for weaknesses and new procedures developed and thoroughly tested before being put into service.

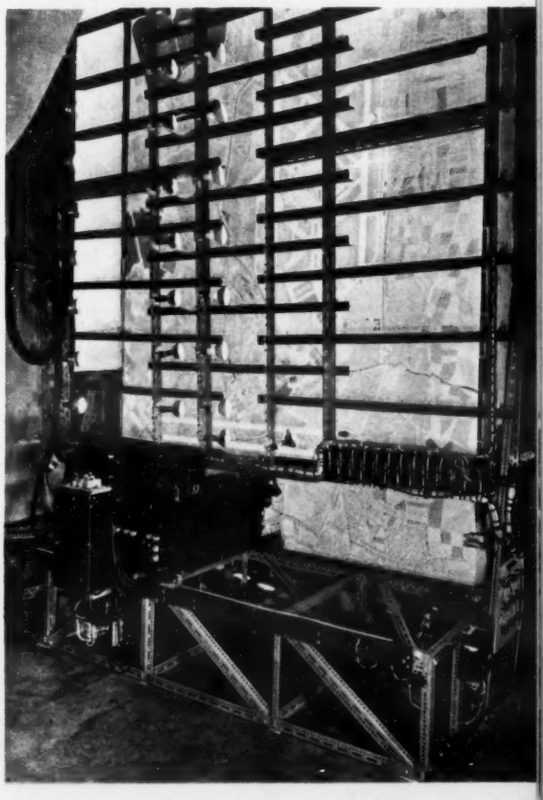
Apart from this, the ATCEU is actively concerned in the development, design, and testing of new equipment and aids for the flight controller's daily work. In close collaboration with the industry, the Royal Aircraft Establishment, the Royal Radar Establishment, the Royal Air Force and all the other British and foreign authorities concerned, the ATCEU is making an important contribution towards increased safety in aviation. ←←

Blackburn Electronic's ADONIS System for the simultaneous pick-up and recording of a large number of measurement data.

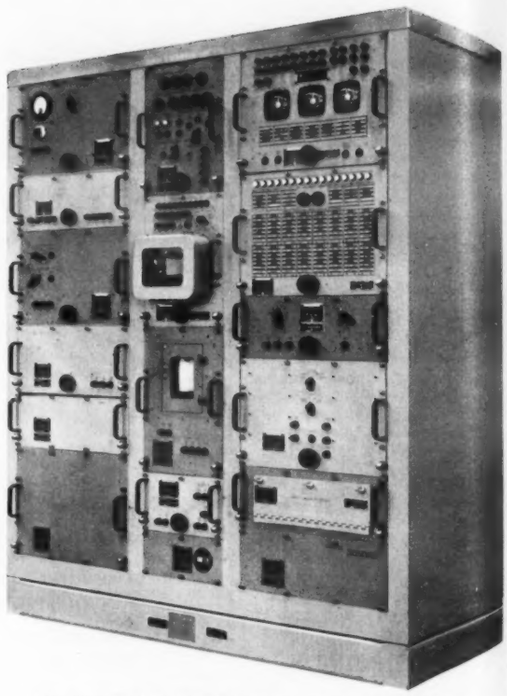


Beme Telecommunications showed a complete ground installation for the control of target drones and guided missiles.

Television camera and map equipment of the *Terravision* auxiliary system for flight simulators, developed by General Precision Systems.



The DATICO Automatic Checkout System



The console of the DATICO checkout system as installed in the fleet ballistic missile nuclear-powered submarines of the US Navy, for the checkout of *Polaris* missiles.

The following article, by an engineer of the Nortronics Division Corporation, underlines the growing demand for automatic equipment for the routine checking of complex electrical systems in aircraft. The unserviceability of aircraft through the failure of a small component of such a system is a frequent occurrence, and the resultant loss of time involved in tracing the fault is out of all proportion. Any equipment which reduces these delays is therefore of great interest. The Governments participating in the European F-104G programme are currently testing various types of automatic checkout equipment, including the Nortronics system described here. Final selection of the checkout equipment to be ordered—there is a requirement for over 100—can be expected in the near future. *The Editors*

The multitude of complex systems and subsystems that comprise today's high-performance weapons makes it impractical, if not impossible, to depend upon individual special purpose test equipment to assure operational readiness. As newer, more complex, aircraft and missiles come into service, the number and variety of separate test units required to check the entire system is multiplying at an alarming rate.

For example, according to US Army logistics data, first and second echelon field maintenance for a battery of *Nike-Hercules* missile requires: (a) a combination of 13 different shop sets, kits and outfits, (b) six separate training courses ranging in duration from 8 weeks for a mechanical repair technician to 41 weeks for a maintenance supervisor, (c) 64 technical publications totaling 5,462 pages of text, and (d) a complement of 91 maintenance technicians. Test equipment, training, and personnel requirements for support of a strategic bomber or Mach 2 fighter are equally staggering.

This creates unwieldly logistics and maintenance problems in the use of test equipment and results in a steadily-increasing burden in money, manpower, and time. In many cases, the cost of separate, special-purpose test equipment approaches the cost of the prime system itself. The level of skill required to operate the variety of checkout units is rising far beyond that normally available in the military services, and elaborate, time-consuming training programs are necessary to assure availability of skilled technicians. Furthermore, the employment of scores of individual system and subsystem checkout equipments in the flight line and at the launch site imposes severe penalties in the time required to verify operational readiness. This trend indicates that a new concept is needed for the efficient checkout of modern weapons.

Ideally, the great number of individual test units should be replaced by a single, integrated automatic checkout system capable of testing an entire weapon system and able to test any subsystem down to the component level.

This requirement for integrated automatic checkout equipment was recognized by the Northrop Corporation as early as 1956, and led the Company to undertake its own detailed study of weapon system checkout concepts. From this study Northrop derived the concept of DATICO (Digital Automatic Tape Intelligence Checkout), a unique programmer, controller, and comparator, which is readily adaptable to a broad range of weapons systems. As compared with the analogue system, the digital offers the advantage of higher speed and provides a printed test result, not merely a "Go/No-Go" answer.

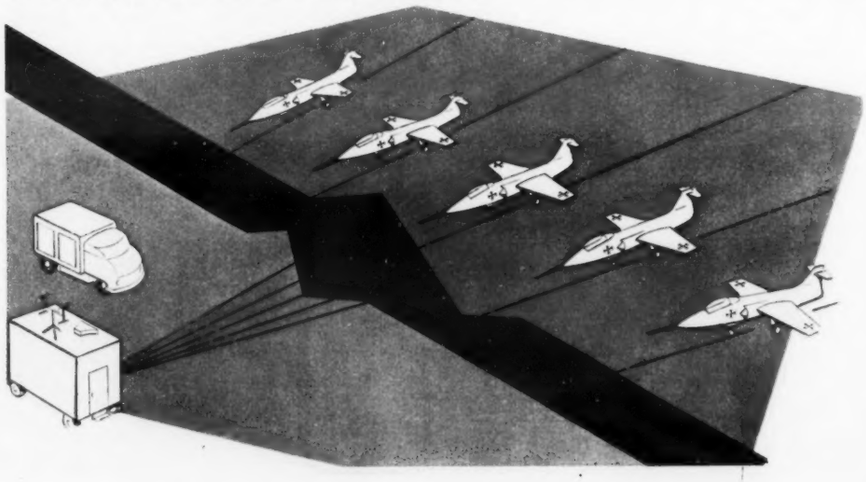
Development engineering began in January 1957 and within eight months the first unit was completed and in operation. Today, DATICO systems are in service with the US Navy, Army, and Air Force, at all maintenance levels, performing automatic checkout for entire weapon systems, as well as subsystems and components.

DATICO is the prime checkout equipment for the *Polaris* ballistic missile weapon system. The sixteen missiles aboard each nuclear-powered submarine are maintained in a state of constant readiness through continuous monitoring and checkout by the equipment. In addition, DATICO units are installed on the submarine tenders for checkout of *Polaris* subsystems at the US Naval Weapons Annex, Charleston, South Carolina, where the depot checkout of these missiles is carried out, and also on the missile production line.

Manned by regular Navy personnel, the *Polaris* DATICO units in the nuclear submarine *George Washington* have logged more than 15,000 hours. During one cruise lasting 28 days, the twin units on board operated around the clock with only one hour of "down time."

DATICO is utilized for Army Ordnance depot verification and malfunction isolation in the *Nike-Ajax, Nike-Hercules, Hawk, Lacrosse, Corporal,* and *Sergeant* missile systems. At Air Force depots, the equipment is operating with a current "down-time" of only 1.7 percent.

The majority of preflight tests are carried out by radiation techniques and no physical connection need be made to the aircraft. Up to nine F.104Gs can be tested simultaneously.



Successful application of DATICO automatic checkout equipment to the maintenance of UHF communications, inertial guidance, radar, armament control, bombing computers, optical and infrared systems, instruments, launchers and tactical missiles has provided unprecedented reductions in time, money and manpower needed to evaluate systems such as these. For example, records show that one application at Davis-Monthan Air Force Base saved the US Air Force $ 250,000 in just six weeks. This type of experience has demonstrated the efficiency and economy inherent in the utilization of such equipment.

As a result, integrated automatic checkout equipment is being applied to an increasing number of complex weapons systems in the US Armed Forces and those of the North Atlantic Treaty Organization. Automatic checkout is ideally suited to high-performance fighter weapons systems, such as the F-104G *Starfighter*, soon entering service with NATO forces, and a variety of other complex aircraft and missile systems. It would of course be possible to use DATICO in the Fiat G.91 single-seat ground support aircraft and certainly in the Northrop T-38.

One DATICO system can checkout the F-104G's F-15A NASARR System, AN/ARC-552 UHF System, AN/ARN-52 *Tacan* System, AN/APX-46 IFF System, Optical Sight, Infrared Sight, M-2 Bombing System, Integrated Flight Control System with Autopilot, PHI-4, LN3 Navigator, Air Data Computer, and In Range Computer. One maintenance technician and two assistants can verify the combat readiness of all these subsystems in just fifteen minutes.

In preflight and periodic inspection, DATICO (1) simultaneously performs "confidence" checks on nine F-104G *Starfighters* on a "Go/No-Go" basis; (2) isolates malfunctions in the aircraft to the most readily removable major assembly; and (3) performs detailed inspection tests on individual aircraft in order to verify the proper operation of the avionic equipment. For base shop maintenance, DATICO provides the means for rapidly isolating the fault in a subsystem down to the lowest removable subassembly or plug-in item, and facilitates testing of removed subassembly or plug-in items which can be repaired in the field. When used for depot or factory repair, the DATICO system will provide the most effective and economical method of repairing removed subassemblies, plug-ins, and line-replaceable major subsystems which are damaged beyond base shop repair capability.

To accomplish the F-104G checkout task, the system performs the functions of self-test, control, measurement, evaluation, and recording. It turns equipment on or off, ranges programmable equipment, starts and stops processes, selects test points for measurement, and positions mechanisms capable of electrical control. Any aircraft system parameters which are expressed in or converted to voltage, frequency, resistance, or time interval are measured. Per-

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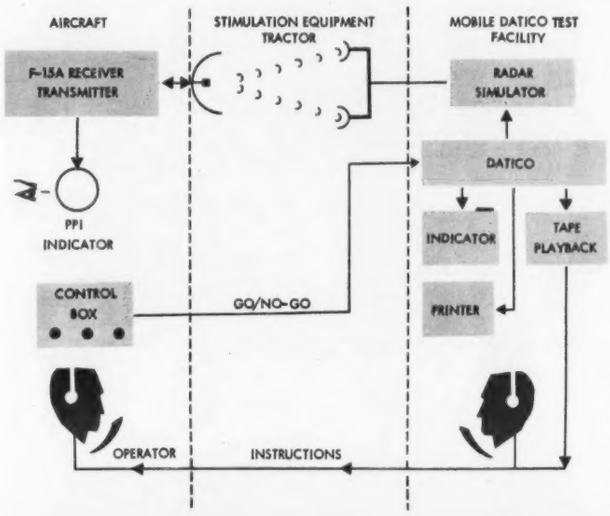
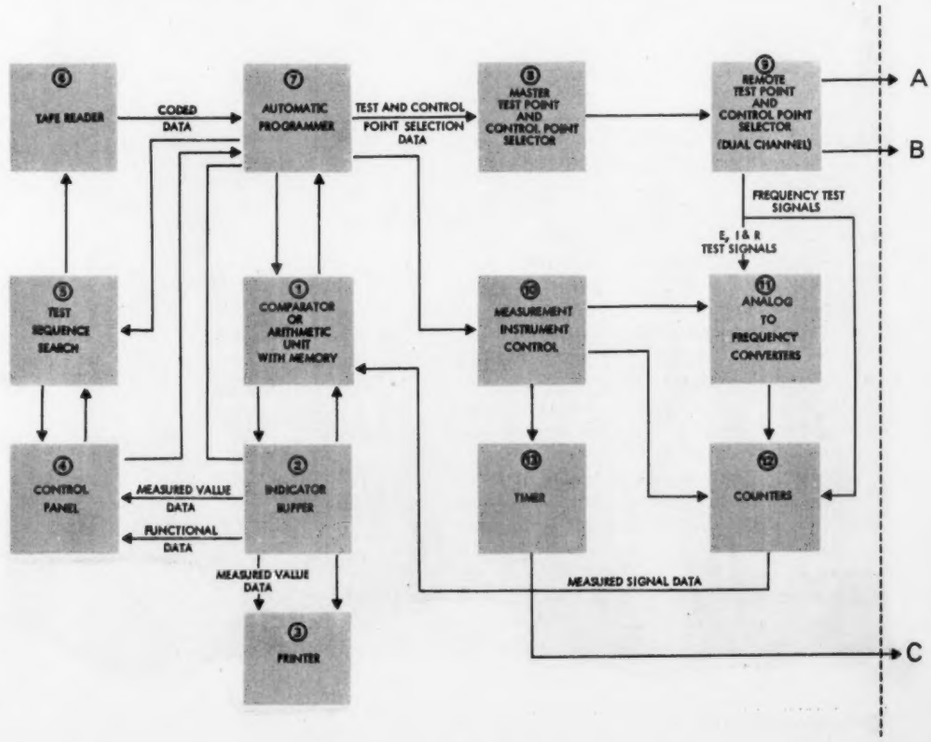
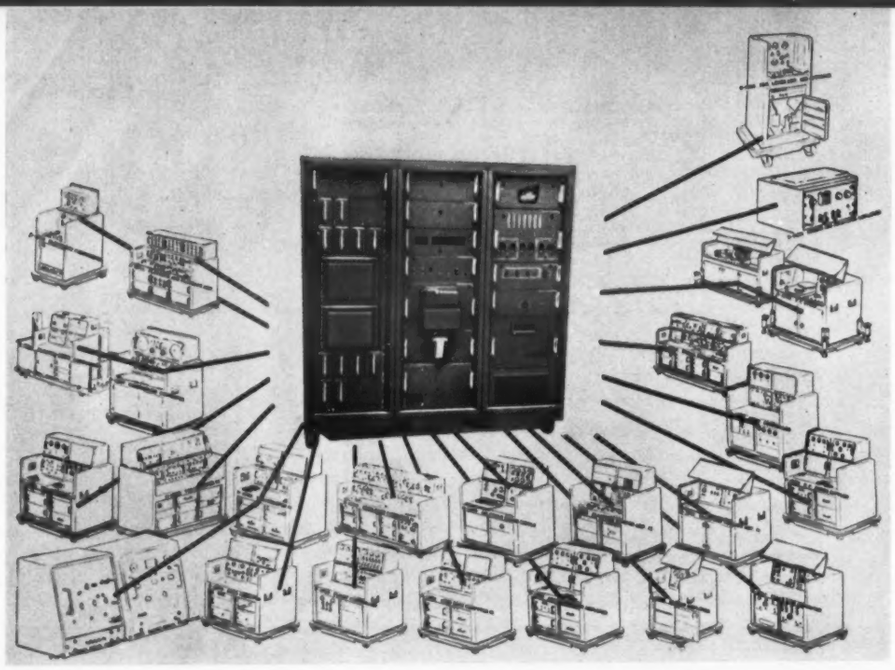


The block diagram of the DATICO system being used for testing the F-15A NASARR equipment. The DATICO issues instructions to the operator in the aircraft through the tape playback and, as each test sequence is completed, the operator signals the result through the control box.

The assembly line for US Navy DATICO units at the Anaheim plant of Northrop Corporation. Two DATICO units are installed on each *Polaris*-carrying submarine.



The schematic diagram of the DATICO system. From the remote test point and control point selector (unit 9) the output A is to up to 100 test point connections per remote unit. Output B is to the control points where up to 30 connections per remote unit can be made. Output C is the programmed time delays for event control.



The integration of 26 separate test units, which were required to test the *Snark* SM-62 missile, into an automatic test system, led to the DATICO concept.

formance is evaluated by arithmetic computation or by comparison of measured values with predetermined limits. A printed record is supplied showing the measured value, the test sequence number, the type of measurement, and the test results. As many as 3,300 different tests can be run from a single reel of DATICO programming tape.

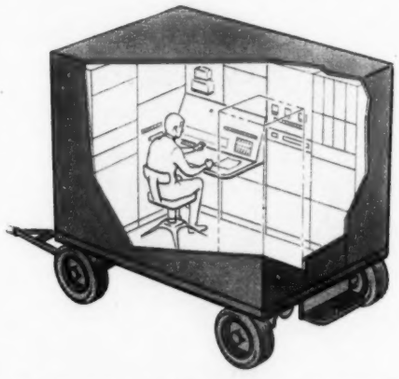
Self-test features of the equipment include monitoring, autocheck and two programmed self-tests. Monitoring of internal programmer circuits is conducted by redundant circuits. Autocheck is accomplished by feedback, each module generating a feedback signal upon reception of the tape program command. The absence of this feedback signal prevents the DATICO from proceeding with the test, and a visual display indicates which unit caused the test interruption.

The testing of the F-104G, or any complex aircraft or missile weapon system, is divided into four classifications: preflight inspection, malfunction isolation and periodic inspection, base shop maintenance, and depot maintenance.

Preflight Inspection

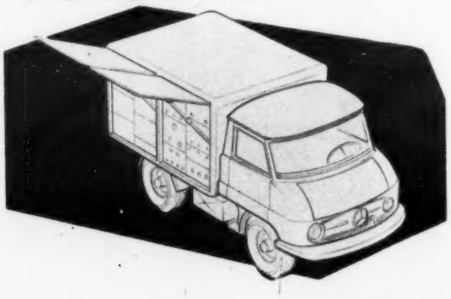
Generally, preflight inspections are performed on combat aircraft at least once a day. If turn-around flights occur, additional inspections are performed. For this type of testing, a minimum number of tests are performed on each aircraft subsystem to verify that the systems are operating. In addition, overall loop tests are performed to ensure that the aircraft subsystems operate together. The majority of preflight tests are conducted primarily by radiation techniques; however, a minimum number of physical connections are made to the aircraft systems.

The mobile DATICO test equipment and the stimulation equipment are directed by the test controller, who commands the testing of all or any one of the test stations. During each system test, "Go/No-Go" information is received by the mobile DATICO test facility from a cockpit operator in each of the nine aircraft which can be checked out simultaneously by the one system. On receipt of a "Go" signal, the systems automatically proceeds to the next sequence. In the event of a "No-Go" signal, a light indicates in which aircraft the subsystems failure occurred. The test controller performing the test has complete control regarding bypassing an aircraft for an individual system failure. Pressing a button on the DATICO equipment will bypass a system test for a particular aircraft. This flight line checkout requires a test controller for the mobile test facility, a stimulation equipment mechanic, and one cockpit operator for each aircraft. The test controller operates the DATICO, communicates where necessary with the cockpit operators, controls testing priorities relative to the aircraft under test, and, in general, controls all testing procedures.



The stimulation equipment trailer which contains all the necessary test stimuli for the F-104G.

The mobile test facility from which the test controller commands the testing of all or any one of the test stations during the flight line checkout.



The cockpit operator receives instructions from the DATICO Verbal Instruction Programmed System (VIPS) via his headset. In essence, the VIPS consists of 40 miniature record players, each of which can be triggered to play its instructions to the operator. Use of 40 short messages instead of one long message facilitates repeating or selecting any message without hunting. When programmed through DATICO, the VIPS will play back its recorded instructions in a preselected sequence, clearly and positively. The possibility of the operator's misinterpreting or even overlooking a test sequence is virtually eliminated. These instructions direct the setup of aircraft instrumentation for a particular test, together with instruments to be read. Upon completion of setup instructions, operation of a READY button by the cockpit operator will permit testing to proceed.

The stimulation equipment mechanic is responsible for moving the self-propelled unit to the aircraft under test and making the necessary connections between the aircraft and the aircraft test terminal. Direct connections are required to provide inputs from an external source to determine operational proficiency.

The F-15A NASARR System, Optical and Infrared Sight System, IFF System, *Tacan* System, UHF System and radiation testing techniques require minimum connections to the aircraft. Cockpit operators are required only to set controls and observe results on cockpit indicators. Aural instructions are automatic, simple, and concise, directing the cockpit operator to move controls and to observe instruments. Test results are determined by the automatic analysis of radiated signals received by DATICO, and by information fed back from the cockpit operator.

In the event of a "No-Go" test result obtained during preflight inspection, the system under test will be subjected to a more rigorous testing procedure to isolate the malfunction to the replaceable major module level. This will ensure maximum tactical readiness of the aircraft.

DATICO is utilized for base shop maintenance primarily for fault isolation to the lowest removable subassembly within a major module that has been determined faulty during malfunction isolation of the aircraft avionics system. The faulty subassembly is replaced and the major module is restored to service or placed in operating spares storage.

The depot test system consists of DATICO test stations similar to those in the base shop, capable of testing major subsystems which have been damaged beyond the repair capabilities of the base shop, and subunits or plug-ins which it is impractical to test or repair at the base shop.

DATICO has a history of successful field operation. Through continuing research in automation, not only have improvements been made in the original DATICO system, but progress has been made toward even more advanced integrated automatic test systems. As weapons become more complex, future systems will be capable of handling the increased checkout requirements. These systems will be solid-state, miniature in size, and high speed; they will incorporate a magnetic memory with random access to data storage and utilize computer techniques for data output. ↔

BIRDIE–
a Mobile System for Air Defence Coordination

The task of modern air defence becomes more difficult from year to year. Even if, for the purpose of this article, we ignore the threat from intercontinental rockets, it is not difficult to imagine what efforts are required to protect a country the size of the USA from air attack. For there is no doubt that any attack with manned aircraft would be a surprise one, involving a considerable number of aircraft carrying nuclear weapons.

The first condition for warding off such an attack is the uninterrupted monitoring of the entire airspace, so that any enemy can be identified as early as possible and the defence weapons brought promptly into play. It is, moreover, absolutely necessary relentlessly to destroy the attacker since, given the hardly imaginable destructive power of the nuclear bombs available today, one cannot afford to let one single aircraft slip through the defence belt.

As long as it is left to each individual anti-aircraft defence unit to find its own targets independently, there is the danger that some attackers are brought down "more than once," whereas others are able to continue their flight unmolested. In order to avoid the wastage of valuable guided missiles through gaps of this kind in air defences, a high degree of coordination between the commander of the guided missile batteries and the higher echelons of command is called for. Within the North American air defence systems, this coordination is effected with the aid of the *Missile Master* system, already in existence, and BIRDIE (Battery Integration and Radar Display Equipment), at present in production for the US Army. The BIRDIE system permits extensive integration of various anti-aircraft defence units with the overall defence system. Whereas *Missile Master* guides the operations of a substantial number of anti-aircraft missiles inside a large territory, BIRDIE has been developed for use in areas where fewer guided missiles are stationed, and where no particularly complicated aerial warfare situations are anticipated.

The entire responsibility for the defence of the North American continent against air attacks lies with the North American Air Defense Command (NORAD). A complex network of radar monitoring and early-warning posts stretches across the United States and into Canada. All observations are collected at the semi-automatic ground environment (SAGE) centres, each of which is responsible for a relatively extensive area. By means of SAGE, NORAD exercises strict control over all air defence weapons, which also include the anti-aircraft batteries of the US Army Air Defense Command (ARADCOM), with *Nike-Ajax* and *Nike-Hercules* missiles.

Consequently, the SAGE centres possess a comprehensive picture of the air situation. The relevant parts of the information available—sorted by operational areas—are continuously transmitted through its own telecommunications channels in the form of digital data to the BIRDIE posts. After these data have been decoded and processed, they

BIRDIE allows the anti-aircraft missiles to be fully integrated with the overall air defence system and makes a vital contribution to increasing America's effective power against enemy air attack.

are memorised on a magnetic drum from which the BIRDIE computer continually calls them up. This memory-drum serves solely as a buffer, since data are transmitted from SAGE to BIRDIE at a considerably higher rate than they can be displayed on the radar screen. The computer is constantly draining the latest information from the memory and displays it on the PPI-screen of the observation console. The computer can process and display on the screen the data received from SAGE (position, course, speed, altitude of the enemy and special identification of own aircraft) simultaneously with information from auxiliary surveillance and heightfinding radars installed in the vicinity of the guided missile batteries. The officer in charge of BIRDIE has thus a comprehensive and exact picture of the tactical air position in his territory.

The same presentation of the air situation is automatically relayed by BIRDIE through its own channels of communication to the commander of each missile battery connected to it. Also at his disposal is the same information on the actual tactical situation and exact target data. In the same way as SAGE transmits special markings for individual radar targets, the officer in charge of BIRDIE can relay information by means of electronically produced symbols of every sort—both to the commander of an anti-aircraft unit and back to SAGE. Nevertheless, more extensive messages are relayed by R/T or telephone links.

This normally means that, as long as the air situation is sufficiently clear, the selection of aircraft to be destroyed is, in the first place, a matter for the guided missile battery commander himself. His decisions are nevertheless reported back to BIRDIE, where, at this point, the officer in charge is now faced with three important tasks. He must avoid two or more missile batteries engaging the same target. Secondly, he is responsible for seeing that missiles are not used against friendly aircraft, and, if necessary, calling an immediate halt pending clarification of the situation. Lastly, the officer in charge of BIRDIE may, from his own knowledge of the overall position or as a result of orders from his superior headquarters (SAGE), allot the missile batteries definite targets. In other words, the use of BIRDIE means that anti-aircraft units are constantly furnished with a picture of the air situation and exact target data, giving optimum distribution of fire power.

A BIRDIE monitoring console with 20in radar screen. The left panel of the console contains all buttons for the control of data input, the switches on the right being for the relay of information.

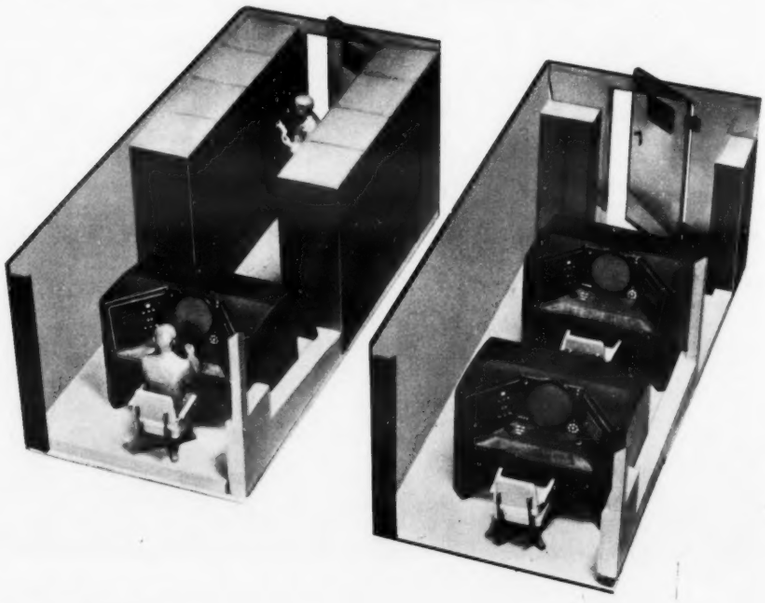
The history of BIRDIE goes back to 1950 when the Martin Company was commissioned by the US Army Signal Corps to develop an experimental system, designated AN/GSG-2, which was then designed for anti-aircraft guns. With the conversion of air defence to guided missiles, the demand for a coordination system became ever more pressing. Since the AN/GSG-2 showed promising beginnings, in 1955 the Martin Company received a contract to develop and manufacture the AN/FSG-1 system, which was christened *Missile Master*. The first unit was ready to be put into service as early as 1957, and today there are ten *Missile Masters* in operation, these being predominantly allocated to the defence of leading cities and industrial centres against aerial attack.

While *Missile Master* is responsible for coordinating the anti-aircraft defences of an extensive area, and can control a considerable number of missile batteries, the demand soon arose for a substantially smaller system capable of fulfilling a similar role, but for a limited area. For this purpose, the Martin Company has developed BIRDIE, the *Missile Master's* little brother, as it were. After the order had been given at the beginning of 1960, only one and a half years elapsed before the first BIRDIE was handed over to the Turner Air Force Base. A second BIRDIE unit is to be used at the US Army Air Defense School in Fort Bliss, Texas, for staff training. To date, a further 17 units are on order, thirteen of which will be delivered this year.

The *Missile Master's* development began at a time when such items as semi-conductor components, printed circuits, etc. had not yet reached the operational maturity of today. No wonder that this system amounts to an extensive plant, requires fixed installations, and boasts a large number of operators. On the other hand, BIRDIE could be described as a transistorised miniature version, for it needs 97 percent less space, 95 percent less power and 80 percent fewer staff than *Missile Master*—not to mention its far lower price. Notwithstanding this, its performance is remarkable. BIRDIE is designed for overall air defence coordination inside an area of, say, 100,000 sq. miles and can "look after" cities with 600,000 inhabitants or important Strategic Air Command (SAC) bases. BIRDIE has the additional advantages of mobility and adaptability. The complete outfit is housed in standard shelters, which can be transported without difficulty by land, air or sea, and no prepared sites are required. Furthermore, BIRDIE can process data from all the radars at present in service with the US Army (surveillance and heightfinding radars) and, should no data from the SAGE centres be available, BIRDIE can carry on working on its own, using radar information obtained locally.

There are, at the moment, two different version of BIRDIE. The AN/GSG-5(V) coordinates and monitors a larger number of missile units and has its own storage and data-processing equipment, as well as equipment for automatic radar-tracking of aircraft targets. The AN/GSG-6, on the other hand, can look after only a limited number of

Various versions of the BIRDIE systems can be linked together in accordance with requirement. Left: a model of the simplest version with only one monitoring console for coordinating and directing four missile fire units and with digital (left-hand row) and analogue (right-hand row) equipment. On the right is a model of a larger BIRDIE system with two consoles. The equipment appertaining to the system is housed in its own shelter.



missile units to which it simply routes information obtained from other stations and locally-computed target data. The smallest BIRDIE version fits in a standard mobile shelter and consists of a monitoring console and separate units for digital and analogue data processing. For air defence coordination in larger territories, two or more shelters can be linked, depending on requirements, to house the more extensive equipment necessary. Except for its power supply, BIRDIE is, accordingly, a compact unit. The required current can be taken from military generators. All inputs/outputs are terminated at the connector panel, thus ensuring minimum setting up time and maximum mobility.

In the development of the monitoring console, particular importance was attached to simplicity in operation, and as a result, the officer in charge of BIRDIE can perform all his functions at a single console. In the centre is the radar screen with a diameter of about 20 in and the track stick, which is used to position electronic tags over targets being tracked by the system. The left side of the console incorporates all the instruments for controlling the input of data, for instance, target information, aircraft identification, radar tracking. On the right are the switches for routing data and information to the missile units.

All components for the digital processing of data—these account for some 80 percent of the BIRDIE system—are fully transistorized and extensive use of printed circuits is made in their manufacture. The development of the printed cards is an excellent example of how specifications for a comprehensive electronic system often force a substantial improvement in the components and the methods of producing them.

The order awarded to Martin early in 1960 was for an inexpensive transportable air defence coordination system, production to begin thirteen months later. It was immediately realised that some 12,000 transistorized digital circuits (gates, flip-flops, etc.) were required for radar target tracking, for data storage and conversion for the various computation processes, and for generating the PPI image.

These circuits had to be cheap and highly reliable, as they were essential to BIRDIE's vital functions. Although Martin was at that time already producing interchangeable circuit cards, these were for special purposes and not in large-scale production; the problem was therefore to develop a production method for the transistorized plug-in cards capable of meeting the high degree of operational reliability called for.

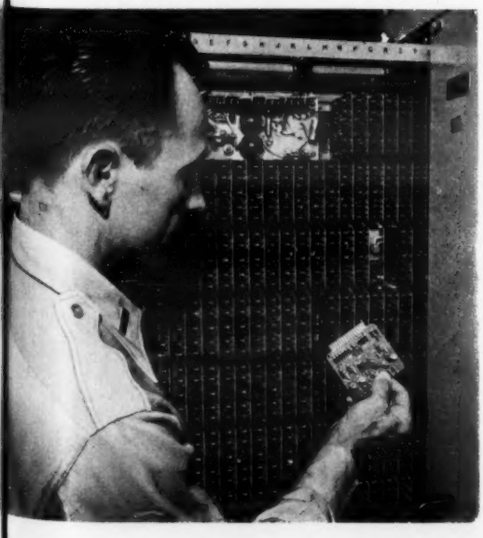
Martin charged two special teams with solving this problem. One was to design the circuits themselves, the other to devise the method of rationally incorporating them in printed circuit cards. The first step in these investigations was to agree on the optimum grouping of the circuits: the decision was five gates or, as the case might be, two flip-flops per card. The next step was to establish a standard size for all the cards, a $3^{7}/_{16}$ in square format being adopted. The total of 12,000 transistorized digital circuits could now be accommodated on 3,000 printed-circuit cards and the number of different circuit cards in this way kept down to 15. In fact, 90 percent of the system is accounted for by only four out of the fifteen types of card, the gate card alone representing 60 percent. In order to rationalise the production of the basic card, a standard pattern of component mounting hole was designed, all of which can be punched by a single punching die in one operation. The standardized interval between the punches has made it feasible to bend and trim the leads of all components automatically.

*

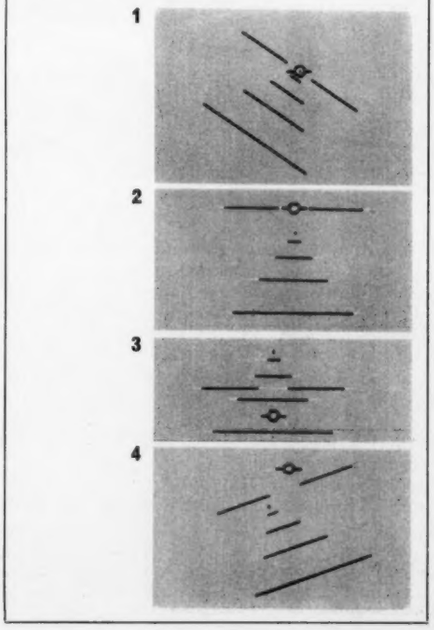
These short examples are sufficient to show the problems which arose in connection with the development of BIRDIE. But they are, after all, no more than important details which are incidental to the fundamental conception. Important as are the price and size of such systems, the overriding consideration is their reliability and operational readiness. ⟷

The standard transportable shelters, in which BIRDIE is housed, measure 18 ft × 8 ft × 7½ ft and can be transported by land, sea, and air, in standard conveyances.

About 3,000 of these plug-in circuit cards figure in BIRDIE's digital data processing system. In developing these cards, equal weight was attached to maximum reliability and ease of maintenance.



An unfortunate error crept into one of the illustrations to the article entitled "PEEP Eye-level Flight Data," (*Interavia* 9/1961 - see page 1276), where the third of the examples was printed upside down. We reproduce here the series of four examples of standard PEEP display: 1 - left bank; 2 - horizontal flight, too high; 3 - descending, too low; 4 - right bank, climbing, too high, off course to the right.



The International Trade Fair at Brno

. . . and the Czechoslovakian Aviation Industry's Jubilee

By E. Baur, Interavia, *Geneva*

The third International Trade Fair at Brno—general view of some of the grounds and the pavilions.

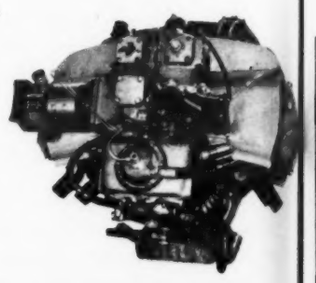
Every year, the town of Brno, located some two hundred miles south-east of Prague, becomes the meeting place of technicians and business men from all over the world. The occasion: the International Trade Fair. Today, thanks to the turbojet service, there are no major difficulties involved in getting there; once you have boarded CSA's IL-18 in Zurich, it is only one hour and a half to Prague and then an hour's flying on to Brno.

We arrived in Prague according to schedule, and the untiring guides allocated to the foreign press representatives made one forget that there are still such things as customs' formalities, even in Prague. A few stamps on our passports and the inevitable accompanying forms... and we found ourselves sitting in the *Avia 14,* which still serves as the standard transport on Ceskoslovenske Aerolinie's (CSA) domestic routes, and which brought us in the finest flying weather to the City on the Shvartsava where the Fair is held.

The site of the exhibition—about 160 acres, with 13 pavilions—included, as before, the stand of Omnipol, the Foreign Trade Corporation which represents the Czechoslovakian aviation industry: a red/white mast with wind-sock visible for miles, the round building which has already served in previous years, and a succession of boards in all languages carrying the slogan "Fifty years of Czechoslovakian Aviation Industry." Just a quick look round the exhibition is enough to reveal the main trend of the aviation section of this year's show, namely *rationalisation of aircraft and engine production.*

The current production programme of the Czechoslovakian aviation industry includes the L.200D *Morava* twin-engined light touring and multi-purpose aircraft, the *Trener Master* two-seat training aircraft, the 3/4-seat *Meta Sokol* sports and touring aircraft, and the all-metal two-seat L.13 *Blanik* sailplane. The *Morava, Meta Sokol,* and *Trener Master* are all still powered by the well-tried Walter M.337 and M.332 engines, with take-off ratings of 210 h.p. and 140 h.p. respectively. Series production of the familiar twin-engined *Super Aero* and *Aero 145,* as well as the *Brigadyr* multi-purpose aircraft, has meanwhile been stopped. With the appearance of its successor, the *Morava,* the *Aero 145,* 80 of which are still used by CSA for taxi services, was doomed. It is nevertheless interesting to note that, between 1945 and 1960 (with several interruptions, admittedly) about 700 aircraft in the *Aero 45, Super Aero,* and *Aero 145* series were finished. During the 2½ years in which the *Morava* has been in production, about 400 have been built, including approximately 300 for export. The *Morava* is scheduled to remain in production for several more years, but the news from the responsible quarter is that a later model with turboprop engines is under consideration. The opinion of Czechoslovakian engineers is that, given the size and purpose of this aircraft, the use of jet turbines can hardly give the best answer.

The L-13 *Blanik* all-metal two-seat sailplane, which is in series production, and is just as suitable for training as for performance gliding. With a span of 53 ft, the L-13 has a wing area of 206.1 sq ft; AUW normally amounts to 1,038 lb. Optimum glide ratio is 29.5 at an airspeed of 56 m.p.h. When flown as a one-seater, the L-13 is fully aerobatic.



A new item on the Czechoslovakian aviation industry's production programme is the M.110H four-cylinder flat-four type engine, a pre-series of which is now in production. The illustration above shows the rear of this engine. *Right:* a general picture of the M.110H, whose output varies between 105 h.p. and 115 h.p., according to its application.

Cockpit of the *Morava* tourer. Both the instrumentation and radio equipment of this aircraft stem now from Czechoslovakia, whereas previously they were largely of Soviet origin.

As to the series Z.26, Z.126, Z.226, the Z.326 training aircraft, which are well-known all over the world, a total of 900 have been built to date, about 250 of these being the most recent Z.326 version. Here, too, export accounts for an appreciable proportion (some 80 percent).

Lastly, there are the impressive *Meta Sokol* (about 200 so far produced, and the *Blanik* training and performance sailplane, 200 first-series models of which went *en bloc* to the USSR. More than 300 of these sailplanes have been built to date and, apart from the Soviet Union, have found customers among other countries in the Soviet bloc, as well as various countries in Europe, Asia, and South America.

The M.110H for Helicopters

A novelty at the Brno Fair was the M.110H 4-cylinder flat-four engine for helicopters and fixed-wing aircraft. As helicopter powerplant, the HC.102 delivers 115 h.p. take-off power and 85 h.p. cruise power. The version for conventional aircraft delivers 105 h.p. and 75 h.p. respectively. The very existence of this engine goes to show that the CSSR is not thinking of giving up the development of helicopters. Although the last few months have brought virtually no news of the two-seat *Heli-Baby* or of the 4 to 5-seat HC.3, Brno left no doubt that intensive work is continuing in this field. The Czechoslovakians naturally do not want to run risks, and will not put this engine into series production until there is an assured market both at home and abroad.

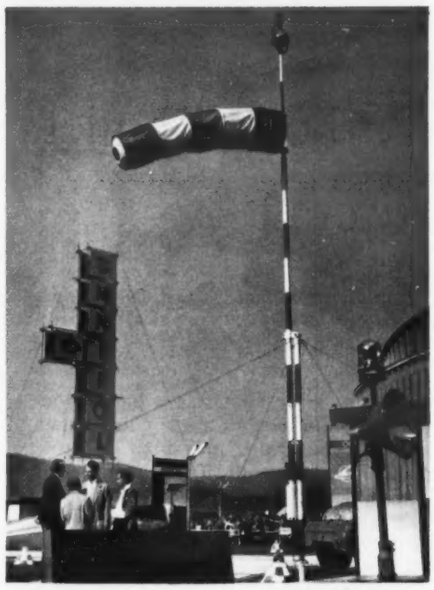
Elektrosignal and Mikrotechna

A much-noted exhibit was the self-contained airport lighting system by *Elektrosignal*. This

complies with ICAO regulations and is planned as equipment for numerous airfields in the CSSR, USSR, and other countries in the Soviet bloc, as well as for airports in Africa.

The lighting system comprises actual runway and taxiing lighting, high and low intensity lights, obstacle warning lights, holding point lights, omnidirectional lights, and other elements. An interesting feature is that the improved ESP-D2 system, now in production, can be set up on any medium-sized airfield in the course of a day and by a minimum of personnel. The connecting cables, sheathed in acid- and weather-resistant plastic, can be laid loosely on the ground. The conductor cable used and the cable design are said to yield an economy in current of up to 200,000 kWh.

Mikrotechna, for a long time well-known as a producer of all kinds of airborne equipment, included in its exhibit at Brno the LUN 1202 artificial horizon which, like all the other Czechoslovakian aviation *matériel*, will be distributed throughout the world by Omnipol. This small, light instrument (it occupies a space of 3,22 in diameter on the instrument panel) is combined with a turn-and-bank indicator, and fitted with a small glow discharge tube to show when the



gyro has reached its operational speed of 20,000 r.p.m. The LUN 1202 is moreover to be transistorised, and hence reduced still further in weight. Another item of special interest is the LUN 1331 remote dual r.p.m. indicator for helicopters, which shows the number of revolutions of both rotor and engine on a common dial.

Amongst the other concerns which attracted interest were METRA, specialised in the field of electronic measuring instruments and distribution and recording devices for industrial and laboratory use, and TESLA of Pardubice, represented at Brno by a display of electronic computers (especially the analogue type).

*

The Brno Fair provided the occasion for international scientific and technical meetings at Prague, including sessions concerned with metallurgy and the working of materials. Future Brno Fairs will demonstrate that these questions have a place in the programme of the Czechoslovakian aviation industry. ←

One unit of a runway lighting system *(left)*; both floodlights can be fitted with coloured filters, as necessary. The light illustrated here consists of two floodlights and one omnidirectional light. The picture on the right shows a conventional runway or taxiway light, one of the components of the completely self-contained Elektrosignal airport lighting system.

Photo top:
Crossway, coding, and holding-point lights by Elektrosignal, Narodni-Podnik, Prague. These intersection lights are of lightweight unit construction and can be set up within a short time, only a minimum of specialists being required. On the right, obstruction light at the masthead. This system is primarily intended for small airports or as a temporary installation. On the extreme right of the picture is an approach light developed by Elektrosignal, with a red obstruction light above. All of these airport lighting units comply with ICAO requirements.

The L.200D *Morava* is powered by two M.337 six-cylinder in-line engines, each of 210 h.p. take-off rating and 140 h.p. cruise rating. These engines have a supercharge and direct fuel injection.

The Combined Turbojet/Ramjet for Supersonic Aircraft

By Claude Flamand, Ingénieur en Chef, Nord-Aviation, Paris

Leaving aside *economic* questions, such as the funds to cover design and development, and the financial resources of the airlines, the date at which the supersonic airliner will actually come into service will depend fundamentally on the following technical factors:

- the materials for the airframe
- the cooling system
- the type of powerplant.

As regards the first point, steel, with excellent strength properties, its ease in welding, and its suitability for use even at high Mach numbers, appears to be the most likely answer.

As to the second, difficulties of effective heat insulation and cooling of passenger accommodation, cockpit, and sensitive components of the aircraft's equipment increase with the Mach number. Whereas, at speeds of up to about Mach 2, traditional methods, further developed as necessary, will do the job, cruising speeds above this level make it imperative to employ special systems. Airframes made of thin corrugated steel could, for instance, be effectively cooled by means of liquid film—a method with the advantage of incurring relatively little extra weight.

It is the third question, that of the powerplant, which is the most controversial. The answers which have so far seen the light of day in the shape of projects, range from the straight turbojet to the turbofan, with and without re-heat. Generally speaking, however, as Mach number increases, the advantages of pure turbo-engines diminish, since, from about Mach 2.5 upwards, their thermal efficiency begins to drop and, in the region of Mach 3, may even reach nil. For this reason, Nord-Aviation's proposal for a transport to fly at high supersonic speeds (Mach 3 upwards) is a turbojet/ramjet combination, designed in such a way that during cruise flight the engine works predominantly as a ramjet.

For any given aircraft, the higher you set your sights in relation to the current state of technical knowledge, the more delicate the choice of powerplant. The supersonic long-haul airliner, whose payload accounts for only a small proportion of take-off weight, is an obvious case of this type and requires adaptation of the engine to the particular operational conditions, if not the development of an engine specially designed to fill the bill.

To facilitate comparison between different types of possible powerplant, it is convenient to group on one and the same diagram all the salient design parameters, namely:

1. Maximum take-off run or acceleration-stop distance, in conformity with international regulations.
2. Maximum take-off speed (180 knots).
3. Engine thrust required for supersonic cruise flight (Mach 3) in keeping with the aerodynamic characteristics of the airframe.
4. Maximum admissible fuel consumption in piercing the sonic barrier (not taken into consideration in Fig. 1).
5. Maximum payload/take-off weight ratio for given range.

By applying these parameters (each represented by a curve) to the same coordinates—wing loading at take-off vs. specific thrust[1] at take-off—we arrive at a series of curves, each of which divides the field into two zones, one in which the parameter is satisfied and one in which it is not, and shows at a glance the zone in which all the parameters are fulfilled. Theoretical optimum compatibility of airframe and engine occurs at the point of intersection of curves corresponding to parameters 1–3 above.

[1] Specific thrust here means the ratio of total take-off thrust of all engines to the aircraft's maximum take-off weight.

A compatibility diagram of this kind is given at *Fig. 1* for the following three types of powerplant, namely:

- straight turbojet without afterburning (A)
- turbofan with afterburning (B)
- turbojet/ramjet combination (C).

The following conclusions can be drawn from the diagram:

- The type of engine has little effect on take-off distance. Acceleration-stop distance is dependent on the number of engines (in our example, four). It can be seen that the take-off thrust of all the engines taken together should correspond to about 30 percent of take-off weight (curves a).
- Maximum limitation of the take-off speed is dependent on wingloading at take-off but independent of engine thrust. The uprights b are valid for a lift coefficient of 0.6 which may be considered fairly typical for a supersonic airliner.
- In cruise flight, total thrust must be equal to the aircraft drag, using an angle of incidence

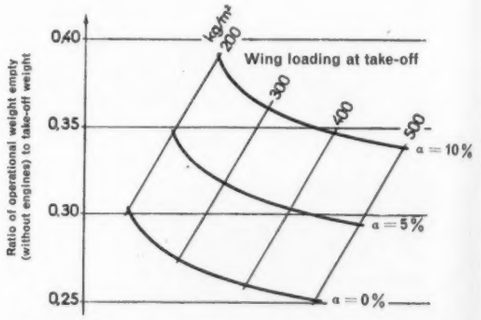


Fig. 2: Effect of wing loading at take-off on the operational weight of the airframe (not including engines) as a function of the percentage of take-off weight represented by payload (α).

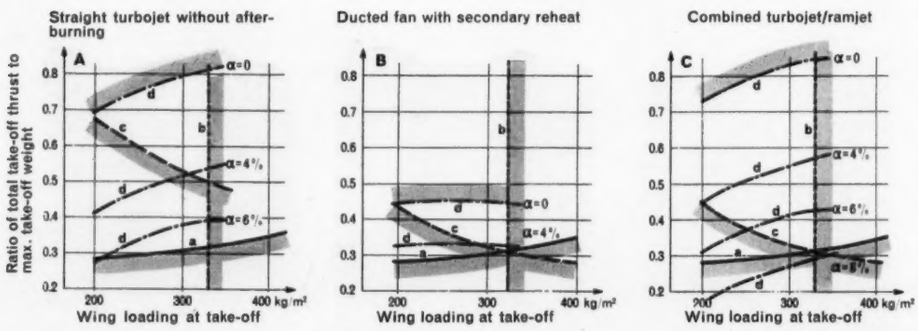


Fig. 1: These three compatibility diagrams, each referring to a different type of engine, illustrate the effect of various design parameters on the payload/take-off weight ratio in the case of a Mach 3 airliner. The superiority of the turbojet/ramjet combination emerges from the right hand diagram.

a — Max. take-off distance or acceleration-stop distance 8,250 ft

b — Take-off speed 180 knots

c — Continuous thrust of engines at Mach 3

d — Percentage of take-off weight represented by payload (α)

which is appreciably below that of the optimum glide ratio (curve c). In order to be able to take account of the cruise thrust of the engine in our diagram, this has to be converted into an equivalent take-off thrust by means of a dimensionless thrust parameter[2]. This thrust parameter is a characteristic value of a specific engine and can be raised simply by increasing operating temperatures in cruise flight or, in the case of the combination engine, by increasing the size of the ramjet relative to the turbine.

• The flight altitude for piercing the sonic barrier should, on the one hand, be fixed low enough to avoid excessive fuel consumption and, on the other hand, high enough to ensure that the intensity of shock waves reaching the ground is acceptable. In any case, supersonic flight must take place above 36,000 ft. In order not to complicate unnecessarily the diagrams of *Fig. 1* the sonic barrier parameter has not been included, since it is for all practical purposes covered by the cruise flight parameter.

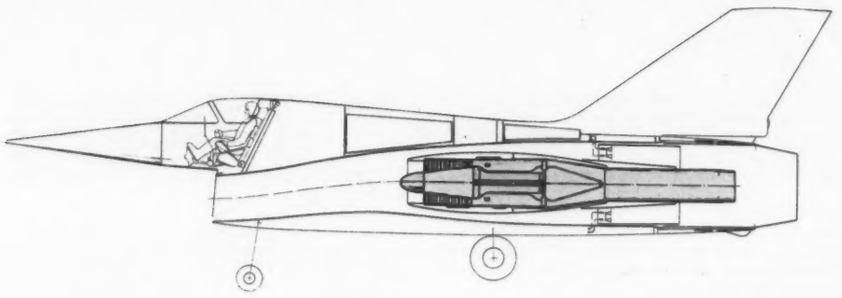


Fig. 4: The combined engine installed in the Nord-Aviation *Griffon 2* experimental aircraft consists of a SNECMA *Atar 101 E3* turbojet surrounded by a ramjet. The geometry of inlet and jet nozzle is fixed.

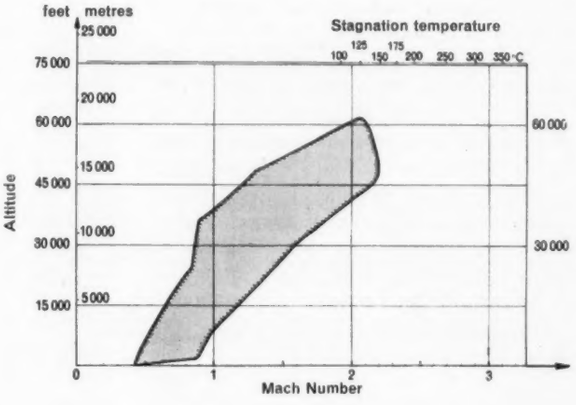
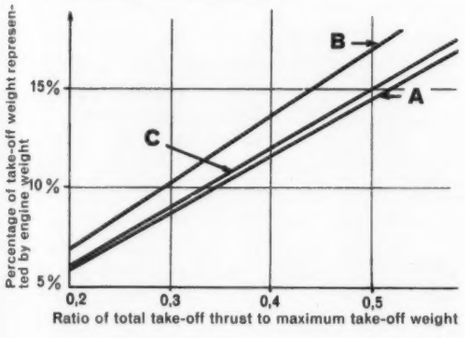


Fig. 5: Performance envelope of the Nord-Aviation *Griffon 2*.

Fig. 3: Percentage of take-off weight represented by engine weight. A — Straight turbojet without afterburning; B — Ducted fan with secondary air flow reheat; C — Combined turbojet/ramjet.



• For a given flight programme the size of payload is determined by the following factors:
- weight and aerodynamic configuration of the airframe
- weight of the equipment
- weight of the powerplant and its fuel consumption in all phases of flight.

All three diagrams at *Fig. 1* are based on the same aerodynamic co-efficients of the aircraft and the same empty weight, which excludes the engines (see *Fig. 2*).

[2] We term "thrust parameter" the expression $T/T_o \cdot P_o/q$, where T is thrust in cruise flight (at given engine r.p.m., altitude, and speed), T_o take-off thrust, P_o barometric pressure at take-off, and q dynamic pressure under cruise flight conditions.

The differences recorded, which relate to the weight of the payload, vary by as much as 100 percent as between the turbojet and the combination engine. As these differences are attributed solely to the powerplant, we propose to examine in more detail the advantages and disadvantages of each type of engine in turn.

The straight turbojet, with its proven quality at high subsonic speeds, loses its advantage at higher Mach numbers. It is, of course, well known that the limitation on turbine entry temperature and on turbine rotation speed lead to progressive worsening of the pressure ratio (total turbine exit pressure to total compressor entry pressure) as the flight Mach number increases. This ratio drops to 1 at about Mach 2.7 and from this speed upwards is inferior to that of ramjet engines.

This drop in pressure ratio cannot be made good by an increase in air input, which is in itself limited by the compressor's absorption capacity; the output coefficient of the compressor decreases as Mach number increases. The result is a continuous reduction in the thrust parameter.

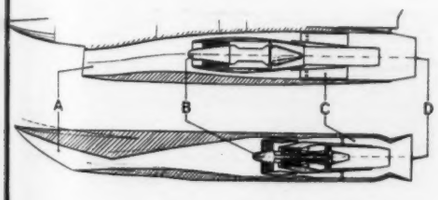
The increase in pressure ratio could, on the other hand, be achieved by raising turbine entry temperature. This solution would however have the disadvantage of reducing the life of the engine and of adversely affecting both its specific weight and its price.

It is therefore fair to say that the straight turbojet without afterburning will not, for a long time, be able to offer a thrust parameter at Mach 3 above unity, even if it is specially adapted for working at high supersonic speeds, and even if the use of maximum thrust in cruise, to the detriment of the engine's life and of its specific consumption, is envisaged. It is, theoretically, possible to power the supersonic aircraft in cruise by using straight jets without reheat, provided a sufficient number of them is installed or oversized engines are employed. In that case, however, take-off thrust would be excessive and the weight of the powerplant would mean a considerable reduction in payload.

The straight jet with reheat would yield the necessary thrust in cruise, with a low installed engine weight. But, even if reheat temperature were restricted to the level strictly necessary, specific fuel consumption in cruise would still be increased by some 20 percent and this would quickly become prohibitive on long-distance flights. The fact that the use of reheat at take-off is in practice ruled out by noise considerations also leads to an appreciable increase in specific weight.

The turbofan is continually gaining in importance in the field of subsonic transport, but as powerplant for the supersonic airliner it is even more unfavourable than the straight jet, unless reheat is used. At high supersonic speeds, a substantial output of secondary air can be obtained only by accepting a large drop in the pressure of the primary airflow, with consequent loss of thrust and increase in specific fuel consumption. Secondary air reheat however makes it possible to increase thrust and reduce specific consumption. By adjusting the rate of reheat, the cruise thrust parameter can be varied and brought to 1.4, or 40 percent better than the straight jet without reheat. Even if turbine entry temperatures of the order of 1,200° Kelvin are adopted, specific fuel consumption remains some 15 percent higher than in the case of the straight turbojet. As in the case of the latter, to increase turbine entry temperature would not yield any improvement in performance

Fig. 6: Typical differences between the engine of the Nord-Aviation *Griffon 2* experimental aircraft *(above)* and that of a hypothetical Mach 3 airliner *(below)*.



	Griffon 2 (Mach 2)	Mach 3 Airliner
A Air intake	Fixed	Adjustable, convergent-divergent
B Turbine	Straight turbojet	Ducted fan; secondary air is led into the ramjet
C Ramjet combustion	Rich mixture	Weak mixture
D Jet nozzle	Fixed, convergent	Adjustable, convergent-divergent

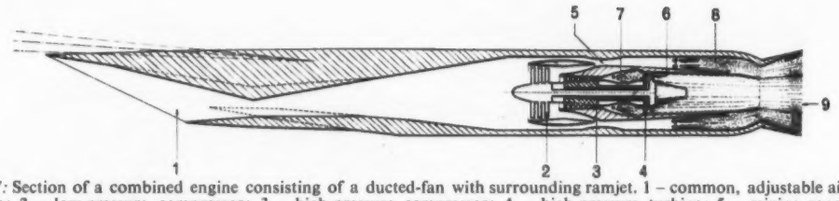


Fig. 7: Section of a combined engine consisting of a ducted-fan with surrounding ramjet. 1 – common, adjustable air intake; 2 – low-pressure compressor; 3 – high-pressure compressor; 4 – high-pressure turbine; 5 – mixing zone; 6 – low-pressure turbine; 7 – annular turbine combustion chamber; 8 – annular ramjet combustion chamber; 9 – common, adjustable jet pipe.

but would be at the expense of the weight, price, and life of the engine.

One can sum up by saying that the two types of engine so far analysed show considerable loss in performance at Mach 3, as compared with their subsonic qualities. For instance, at subsonic speeds a turbofan engine of relatively low compression ratio capable of Mach 3 consumes 10–20 percent more fuel than the turbofans currently in operation.

The combined turbojet/ramjet engine conceived by Nord Aviation marries the turbojet and ramjet in such a manner as to foster favourable interaction in the operation of the two elements, and achieves results which cannot be obtained by merely juxtaposing two engines. In this layout, the turbojet and the ramjet are arranged concentrically in the same duct, fed by a common intake, and with a common exhaust. At low speeds, the turbojet is in its element and does most of the work. At Mach 3, the ramjet takes over practically solo and delivers the entire thrust, its specific fuel consumption being the same as the straight turbojet without reheat, since the pressure ratios are about the same. All that is required is to establish the dimensions of the ramjet corresponding to the desired thrust.

Interaction between turbojet and ramjet is most marked in the neighbourhood of Mach 1 and in the lower supersonic range, up to Mach 2 or so; it is here that difficulties are liable to arise. Thanks to experience obtained with the *Griffon 2* research aircraft *(Fig. 4)*, Nord-Aviation is in a position to design combined engines in which both partners work with optimum efficiency. *Fig. 5* shows the performance envelope of the *Griffon 2*, which more than covers the "difficult" range of Mach numbers. For Mach numbers above the *Griffon's* performance envelope, Nord-Aviation has obtained the requisite data from ramjet trials with powered drones.

For the *Griffon*, originally designed as a fighter-interceptor, it was mainly a matter of low weight and high thrust, noise at take-off being of little importance. In the supersonic airliner, on the other hand, fuel consumption is the decisive factor. If the engine is to work economically both in cruise and at supersonic speeds, air intake and thrust nozzle geometry must be variable.

Fig. 6 shows the evolution of such an engine. The secondary air of the turbojet is mixed with the ramjet air, and the ramjet combustion chamber is fed by this mixture, which allows reheat of the secondary output of the turbojet without the need for an extra combustion chamber. This arrangement produces substantially more thrust in the neighbourhood of Mach 1, and even at take-off slight heating of the secondary airflow allows thrust to be raised by about 30 percent with noise below the level of today's turbojets.

The fact that in cruise at Mach 3 a combined engine of this type does not require a high turbine entry temperature favourably affects both its price and its life. Lastly, this design offers important advantages in the event of the sudden failure of one turbine, namely:

- at take-off, increase of reheat in the engines which are working easily compensates for the thrust of the one which has failed;
- in supersonic flight, the ramjet duct creates a natural bypass for the excess air in the turbo duct, and special automatically variable nozzles can be dispensed with.

For cruise flight in the region of Mach 3, we have based ourselves on the following coefficients for the combination engine:

Thrust parameter: 1.4
Specific fuel consumption: 1.55 lb/lb/h
Max. engine temperature: 1,000° Kelvin (in the ramjet flow)

As can be seen from *Fig. 1*, the optimum wing loading for the three types of engine considered is about 300 kg/m². Based on the corresponding values for specific take-off thrust (total thrust divided by take-off weight) we have established, for each type of engine, a breakdown of weights in the case of a commercial aircraft, capable of using normal runways and of carrying 125 passengers for a distance of 3,700 statute miles at a cruising speed of Mach 3. The results, and in particular the ratio of payload to take-off weight, are shown diagrammatically at *Fig. 8*.

The example which we have used for the calculation of direct operating costs, based on the foregoing, has a maximum take-off weight of 385,000 lb, 49 percent of which is fuel (ATA June 1960 method). The results are given at *Fig. 9*. The scale on the right shows block time, and that on the left direct operating costs in dollarcents per seat-mile. On typical long-haul routes (2,000–4,000 miles), the operating costs of Mach 3 aircraft are roughly comparable to those of a subsonic jet airliner. Whilst these costs rise as cruise Mach number decreases, they nevertheless remain low enough to enable the inclusion of 500 miles or so of subsonic cruise in the flight plan. →→

Fig. 8: Effect of type of engine on weight breakdown of a Mach 3 airliner capable of transporting 125 passengers over a distance of 3,700 miles. A – Straight jet without afterburning; B – Ducted fan with secondary air flow reheat; C – Combined turbojet/ramjet.

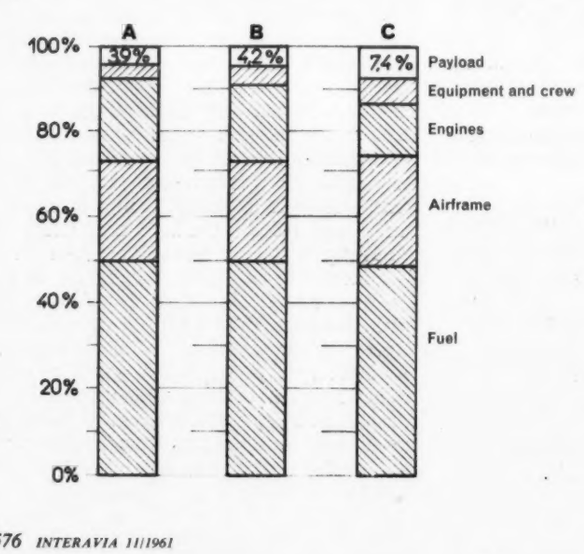
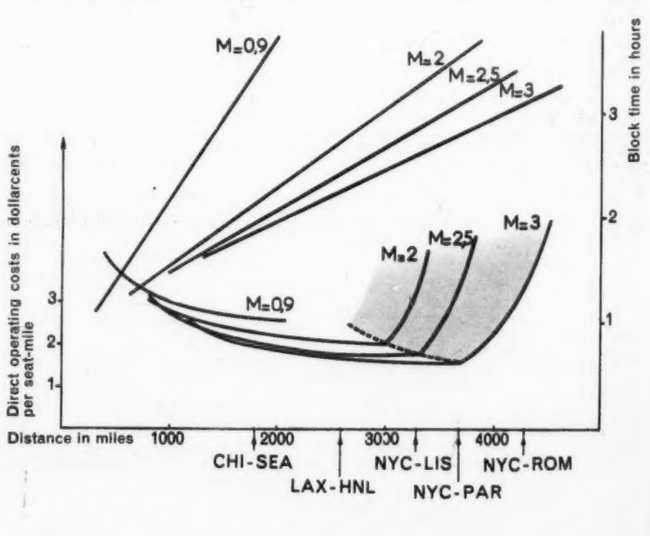


Fig. 9: Direct operating costs for a Mach 3 airliner powered by combined engines for the transport of 125 passengers over a distance of 3,700 miles. The shaded area indicates a reduced payload. Abbreviations: CHI – Chicago; SEA – Seattle; LAX – Los Angeles; HNL – Honolulu; NYC – New York; LIS – Lisbon; PAR – Paris; ROM – Rome.



Book Reviews

Modern Flight Dynamics.—By W. Richard Kolk.—Prentice-Hall, Inc., Englewood Cliffs, N.J., 1961 (English; 288 pages with numerous figures and diagrams).

This volume originated from a series of lectures on dynamics delivered at the Martin Education Department and the United States Naval Test Pilot School. At first glance, one has the impression of being confronted with a dry, highly scientific text-book. And authoritative it undoubtedly is. But it also emerges that the author treats the problems of aerodynamic forces which arise in flight (both rockets and aircraft) in a very lively and impressive manner. Equations of motion are not, as is often the case, reduced to non-dimensional status and the author keeps to the "body-fixed" axis system.

Discussion of general principles of mechanics and dynamics, which assumes familiarity with higher mathematics (Lagrangian equations, etc.), and a chapter on aerodynamic forces and moments are followed by treatment of modes of motion about the three axes of flight. Considerable space is then devoted to two chapters on reversible and irreversible control systems. The last three chapters cover aeroelasticity, "Rockets: as they tumble and spin", and a short thirteenth chapter on celestial mechanics. There are several appendices devoted to mathematical calculation methods, and an index. Ge.

L'aviation en Afrique noire d'expression française.—By Jean-Paul Rey, Docteur en Droit, Diplômé de l'Institut d'Etudes Politiques de Paris. Published by La Librairie générale de droit et de jurisprudence, R. Pichan and R. Durand-Auzias, Paris, 1961 (French; paper-back; 189 pages with numerous tables and maps).

In 1958, the author presented his thesis on "the role of aviation in the economic development of French Africa," for his doctorate of law in Paris. Now, Dr. Ray has produced a very comprehensive work, which takes account of the deep-seated political changes in Africa since 1958. Aviation problems in Africa are examined from the point of view not only of the continent's economic development, but also of its political and social evolution.

After some pages of general introduction, which bring out the importance of aviation in the development of all aspects of black Africa, the author begins with "the basic facts of air transport in French Africa" in which he successively analyses its growth, its mission, and its economic aspects.

The chapter dealing with the commercial operating factors relative to air lines in Africa—even if these factors are not strictly the same today—seem particularly interesting at a time when Air Afrique is negotiating its first scheduled commercial long-haul service, and plans 25,000 flight hours by DC-4 in 1962.

In the second part, entitled: "The contribution of aviation to the economy of French Africa," the author deals with the aircraft's role in black Africa, in relation to both passengers and freight. The last chapter, which compares the part played by surface and air transport, is very informative. The conclusion of this study is objective and cautious. This is understandable, considering the amazing rate of development in Africa. The numerous tables and maps are contained in an appendix.

This work is intended for politicians, teachers and economists, as well as for all those—technicians or laymen—who are interested in air transport, or in French-speaking African states and their problems. Considering the value of its contents, it is a pity that it is not better produced. Ga.

Flugzeug-Turbinentriebwerke.—By Josef Frötschel.—Privately published by Ing. Josef Frötschel, Hamburg-Fuhlsbüttel, 1960 (German; 140 pages, 80 illustrations and five tables; paper-back; price DM 7.50).

Turbine-powered traffic is growing, and this naturally heightens the interest in turbo-engines. In recent years, however, such a large number of new types have been brought out that it is gradually becoming quite a problem to remember the designation of every type. The author, an instructor at the Lufthansa Technical College at Hamburg-Fuhlsbüttel, explains in the foreword that, whilst his booklet on modern turboprops and turbojets is intended principally for the professional, it should also interest many readers outside this category. Without being over-technical and employing only a minimum of formulae, this work deals with the following subjects in its ten main chapters: the history of the turbine; turbine engine classification; basic technical categories of turbine engines; methods of increasing power; turbine engine components; turbine engine systems; special installations; engine monitoring; safety systems; materials, fuels, and lubricants. The text is complemented by numerous instructive illustrations. The English technical terms (quoted in brackets after the German) form a useful addition, but they are not always easy to find quickly. In later editions, an index of German and English terms might usefully be added. The author is also preparing a supplementary volume, entitled "Flugzeugturbinen im Betrieb," covering the monitoring, maintenance, and location of faults in turboprops and turbojets. De.

Wasser als Löschmittel.—Anwendung und Technik im Brandschutz. — By Dr.-Ing. Oskar Herterich. Volume II of the "Bücherei der Brandschutzwissenschaft und verwandter Gebiete", edited by E. Baum, K. Möbius, and L. Scheichl. — Dr. Alfred Hüthig Verlag GmbH, Heidelberg, 1960 (German; 236 pages with 98 illustrations; cloth-bound; price DM. 28).

This work, which is based on the results of research undertaken in many countries, starts with a general chapter on the characteristics of water (pure or with additives), its application (with additives as foam, or as mains water), and its delivery. It then goes on to deal with the actual technology of fire-fighting. The physics of the full jet, the spray jet, and water vapour are explained thoroughly but, at the same time, in a way comprehensible to the "man at the hose." There is no lack of practical examples and "tips" both for the research and development engineer and for the jet hose operator. Further specialized volumes in this series, which will deal with the technology and tactics of fighting fires, are in preparation.

As regards fires occurring in the aircraft industry and in the operation of aircraft generally, highly explosive materials are, in many cases, involved. This rules out the use of pure water, and the specialists in this field should, accordingly, find the chapter dealing with the use and effect of air foam of particular interest. The appendix contains a comprehensive bibliography. Ge.

Strategy and Arms Control.—By Thomas C. Schelling and Morton H. Halperin.—The Twentieth Century Fund, New York, 1961 (English; 148 pages; price $2.50).

The work of two eminent scholars, both members of Harvard University's Center of International Affairs, this study grew out of the authors' participation in the discussions of a group of scientists—physical and social—that met during the summer of 1960 under the auspices of the American Academy of Arts and Sciences, with the financial support of the Twentieth Century Fund. So much for the "credentials."

The authors say that they believe arms control to be a promising, if still only dimly perceived, enlargement of the scope of military strategy and the volume is, in essence, a development of this theme. This book is not a plea for disarmament, still less an impassioned one, but a hard, business-like examination of arms control in relation to military strategy and foreign policy which, realistically enough, uses the USA/USSR "case" as its model.

One of the theses which the authors advance is that to provide secure and well-controlled nuclear forces, together with secure command communications to back them up, which are to be capable of retaliating no matter how great the initial destruction by enemy attack and without dependence on hasty response to ambiguous warning, could well mean an increase in arms expenditure; this would not contradict the spirit of arms control in their sense.

The discussion ranges over the potential security functions of arms control, the evaluation of arms combat proposals, and making arms control work. At nearly every juncture there are thought-provoking passages—partly in the form of new ideas and partly in the critical examination of old ones.

Many will differ radically from some of the authors' arguments, whilst many will substantially agree. Few, however, will deny that this is a well-written and thoroughly stimulating book, which deserves attention. It should certainly be compulsory reading for statesmen and at military staff colleges, including, if that were only possible, those in the Soviet Union. MT.

The Conquest of Space.—By Albert Ducrocq.—Translation from the French; originally entitled "Victoire sur l'Espace".—Putnam & Company Limited, London, 1961 (English; 300 pages with numerous illustrations and photographs; cloth-bound; price 30s.).

To write about space is no longer as easy as all that. Rockets travel fast, and foreseeable developments are overtaken all too quickly by reality. This book is nevertheless welcome in making the science of space accessible to the general reader. Starting from a summary of what has already been achieved, the author takes us on through the exploration of the atmosphere, the earth's radiation belts, man in space and Lunik II and its guidance, to voyages to Venus and Mars. In the appendix are details, and some formulae, relating to the elements of spatial ballistics, planetary trajectories, speed calculations, as well as Lunik 3 and the flight round the moon. De.

Gas Sampling and Chemical Analysis in Combustion Processus.—AGARDograph 47.—By G. Tine'.—Pergamon Press, Oxford, London, New York, Paris, 1961 (English; 94 pages with 55 illustrations and 5 tables; price 42s.).

Among the most important aids in research on combustion phenomena is the chemical analysis of the gas mixtures concerned. Such analysis, however, requires the drawing of representative samples which, given the extreme speed and, often, the non-steadiness of combustion phenomena, is a very difficult problem.

In view of the importance of this field for the development of all types of engines, the Combustion and Propulsion Panel of AGARD decided to sponsor and publish a monograph. The author, who is Professor of Applied Mechanics at Naples University, was given the opportunity of visiting about 30 modern combustion laboratories in Germany, England, France, and the USA, and of discussing the problems of the relevant experimental techniques with many scientists.

The book accordingly summarizes the present state of the art. The author has, of course, not written a text-book but presents only results and conclusions, which are however the subject of critical comment and are supported by 127 references to literature. A thorough knowledge of chemistry and the mechanics of combustion are indispensable to an understanding of this work. Pro.

Space Astrophysics.—Edited by William Liller, Professor of Astronomy at Harvard University.—McGraw-Hill Book Company, Inc., New York, Toronto, London, 1961 (English; 272 pages with numerous photos, diagrams and sketches; cloth; 77/6d sterling).

This volume is one of the series of the Institute of Science and Technology of the University of Michigan, it is a collection of illuminating lectures, by some of the most eminent specialists in the world, on aspects of astronautics and astrophysics which are either concerned with, or can only be studied from, outer space. The material covers a number of the most recent scientific advances in this field, but advanced knowledge of the subject matter on the part of the reader is assumed.

The work is divided into three sections. First, *The Experiments*, including discussion of the ultra-violet electroscopic analysis of the sun and photometric astronomy carried out from rockets. Second, *The Theory*, which deals with solar winds, the solar corona, interplanetary gases, the moon, and the electric universe. The last section, entitled *The Instrumentation*, gives a detailed description of astrophysical research carried out by means of artificial satellites and space probes. At the end of each lecture there is an extensive bibliography. A short general index is provided at the back.

In short, this book is clear, concise, and well documented. It will be of great value to the scientist and the engineer, who will find in it a large quantity of hitherto unpublished scientific information. Ye.

AEG-Hilfsbuch (eighth edition)—Published by the Allgemeine Elektrizitäts-Gesellschaft.—Verlag W. Girardet, Essen, 1960 (German; 728 pages, 1052 illustrations and 221 tables; cloth-bound; price DM 27.80).

There have, in the past 40 years, been eight editions of the AEG handbook, and it has been translated into English, French, and Spanish. This success speaks for itself. Seventy members of the AEG staff have completely revised this edition, bringing the work completely up-to-date. From the construction of the atom to the most complicated technical process and equipment, both the professional and the student will find a wealth of information. The generation, distribution, and application of electrical energy are presented in a comprehensive easy-to-understand manner. The chapter on measuring and guidance techniques and those dealing with communication and long-range techniques have been prepared with particular thoroughness. The clear overall presentation of the material is deserving of particular praise; subheadings and many explanatory diagrams figure in the wide margin, and a large number of tables, diagrams and circuit plans help to ease understanding. Copious appendices cover notation, units, conversion tables, the conventional symbols of circuitry, and so on. A subject index conclused this work, which is not intended as a text-book but as a reference work for engineers and apprentices. The technical specialist will of course have to find technical works in his own field, but he will always be glad to have the AEG handbook to turn to when faced with a problem from another field. Eb.

Corrigendum. In an article in *Interavia* 7/1961, page 1007, describing the New North-Seeking Gyro Compass manufactured by Messrs. Anschütz & Co GmbH, the maximum error of any individual reading was erroneously stated as being "±3.4 radians" This should have read "±3.4 minutes of arc", and it is desired to apologize for any inconvenience caused by this mistake.

Letter to the Editor

A year has now passed since you published an article by Professor Liljequist regarding Comm. Byrd's flight to the North Pole in the *Josephine Ford*. I had expected vigorous opposition against some assumptions advanced in that article, but this has so far not been the case. Since my youth I have always been very interested in the flights of the great pioneers. I have made a study of the technical aspects of the *Josephine Ford* and wish to send my report of some investigations I have made during the summer of 1960. As this subject is most extensive, I should like to give a very short summary of my results.

Professor Liljequist says that Byrd probably did not reach the North Pole, and as main reason for his statement he forwards the opinion that the *Josephine Ford* was too slow an airplane.

Professor Liljequist bases his opinion on the following facts:

1. The notes in log-books of later flights with the *Josephine Ford*.
2. The flying-time that Lieuts Maitland and Hagenberg used on their flight in a *Fokker* aircraft in June 1927 to Honolulu.
3. Flying tests with a *Fokker* at the Naval Air Station of Anacostia in October 1927.

Anyone who has been occupied with flight testing knows what demands have to be made on the measuring methods in order to determine the speed performance of airplanes. I believe that no expert would want to use log-book notes as a basis for conclusions of speed performance of airplanes. We can, therefore, leave the log-book notes out of this investigation.

Further, I cannot accept the other points. The fact is that the Honolulu plane and the Anacostia plane were of a different type from the *Josephine Ford*, in spite of the fact that they were all misleadingly characterized as *Fokker F VII-3m*. The different planes had the following characteristic dimensions:

	The Josephine Ford	The Anacostia and the Honolulu planes
Wing area (m²)	58.5	67
Span (m)	19.3	21.7

The *Josephine Ford* consequently was thus essentially smaller and had therefore less drag than the two other planes, and accordingly the performances of these planes cannot be taken as a reason for the assumption that the *Josephine Ford* could not make the North Pole flight.

May it perhaps be that the Josephine Ford *was not capable of making the North Pole flight apart from the incorrect speed assumptions in the article mentioned?*

In my effort trying to answer this question I have investigated:

The *drag* of the *Josephine Ford*,

The *wind conditions* in consequence with the drag, and

The *fuel consumption*

It would be too long a story to describe in detail the investigation in its entirety. I have however based my investigation on official flight tests with different Fokker planes and on elementary aerodynamical methods.

Drag

I have tried to define the drag of the plane *within limits inside of which the drag of* Josephine Ford *certainly will stay*.

Further I have calculated *how great the drag of the* Josephine Ford *may be* in order to make the North Pole flight possible.

In so doing I have found:

1. That there is a good margin between the possible drag, deduced in this way, and the permissible drag.
2. That even if a rather high drag area within the calculated probable limits of the drag area is assumed, the *Josephine Ford* is capable of making the flight without the help of any favourable wind conditions, and that Byrd's schedule can very well have been kept.
3. That there will be a 20 percent margin of the drag used in 2. above left before the drag is so great that the flight cannot be realized.

Wind Conditions

Professor Liljequist arrives at conclusions concerning wind conditions from Byrd's flying times which, in conjunction with his assumptions regarding the performance of the airplane, may not be quite correct.

As the flying time to the North Pole was 8 hours 26 min. and the time for the return flight was 6 hours 52 min. this difference must, according to the Professor, be explained by a more or less constant wind from the north with a speed of 10.6 knots. If, as Professor Liljequist has done, you assume a constant flying speed of 162 km/h a wind velocity not of 10.6 knots but of 9.2 knots, will be necessary from the North Pole to Kings Bay, in order to make Byrd's flying time correct. After having made still more assumptions based on supposed speeds of the *Josephine Ford*, Professor Liljequist comes to the conclusion that the wind must have blown with Byrd to the North Pole with a velocity of about 5 knots, and that there the wind must have turned with Byrd and aided him on the return flight with a speed of about 22 knots or, if the wind had aided him only on the first half of the return flight, with a speed of 40 to 50 knots.

Such a strong wind cannot be confirmed from meteorological maps and has not been recorded on Spitsbergen at the actual time. Therefore, Professor Liljequist concludes, Byrd cannot have reached the North Pole.

This argumentation is not acceptable because the argument is based on assumptions of the speed of the plane.

The speed of the plane also is not constant. As the weight of the plane decreases with the consumption of fuel, the speed of the plane will increase.

If you make a *schematic* calculation of the speed of the *Josephine Ford* based on a rather high drag within the probable limits of drag area and add a constant power of 160 Hp/engine, you will find that the flying speed relative to the ambient air will be 155 km/h at the beginning of the flight, 165 km/h at the turning point and 170 km/h at the return. To make Byrd's schedule true, it is thus necessary to assume a constant wind from the North Pole to Kings Bay of about 6.5 knots.

This wind assumption will make Byrd's flight more difficult but it must be observed that even with this unfavourable assumption it is possible to reach the North Pole within the time Byrd has stated.

In reality, there have been disturbances which have prevented the flight from being made in the schematic way mentioned above. These disturbances partly reflect the time difference between the flight to the Pole and from the Pole, so that a still lower wind velocity can be accepted.

This wind velocity may very likely have been between 5-10 knots from the north and yet Byrd's time can be kept. If these wind conditions can be accepted, then all of Byrd's information regarding the wind can be accepted, that is, that there was about no wind at all during the flight to the Pole, and a relatively strong or medium wind on the first half of the return flight.

Fuel consumption

Concerning the fuel consumption, I have found:

1. That, without any favourable assumptions, the flight can be made with a fuel consumption of less than 600 gallons.
2. That fuel consumption may have been around 560 gallons if, as is probable, the wind conditions were such as Byrd says, namely no wind at all on the way to the North Pole and medium tailwind on the way back or on part of it.
3. That in the take-off weight of around 10,000 lbs, there is enough compass to include 660 gallons, and that Byrd probably intended to use 700 gallons including 160 gallons in separate cans. (A certain number of these cans plus one man had to leave the plane before the final definitive take-off for weight reasons).

According to my investigations, from which I here have quoted only the results of the most important points, I wish to state as my opinion that Byrd with the Fokker plane *Josephine Ford* had good technical possibilities to make the North Pole flight on May 9th, 1926.

I enclose a summary of my technical investigations in this matter.

Linköping. Erik BRATT,

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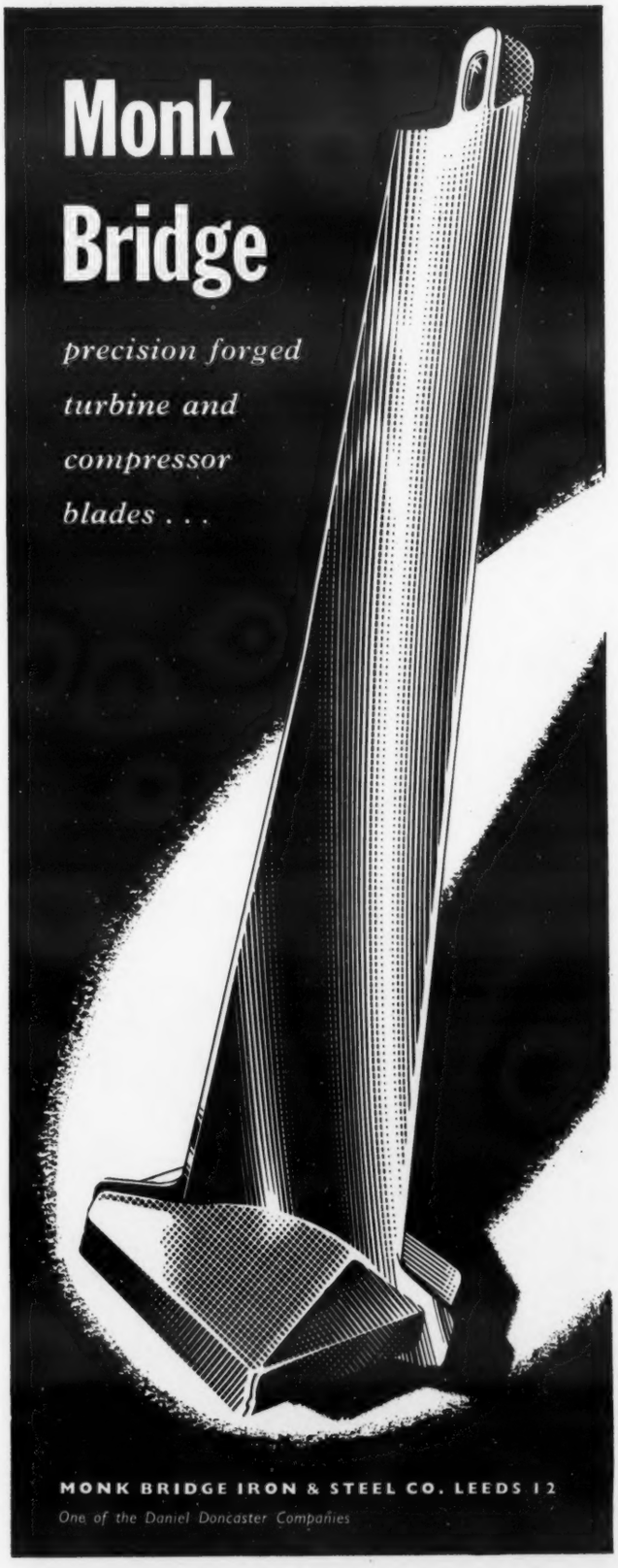

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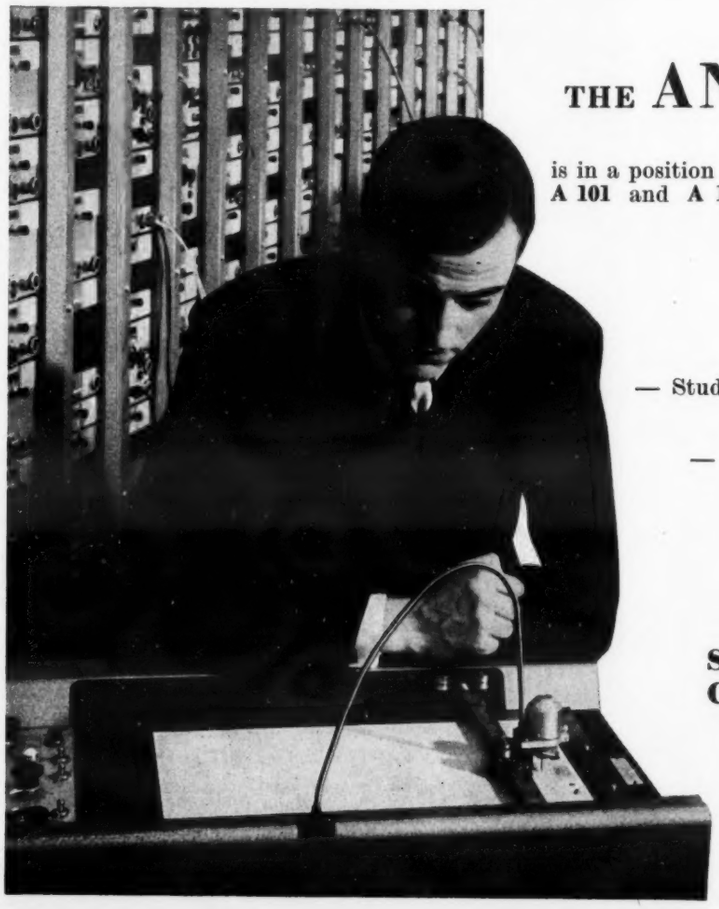

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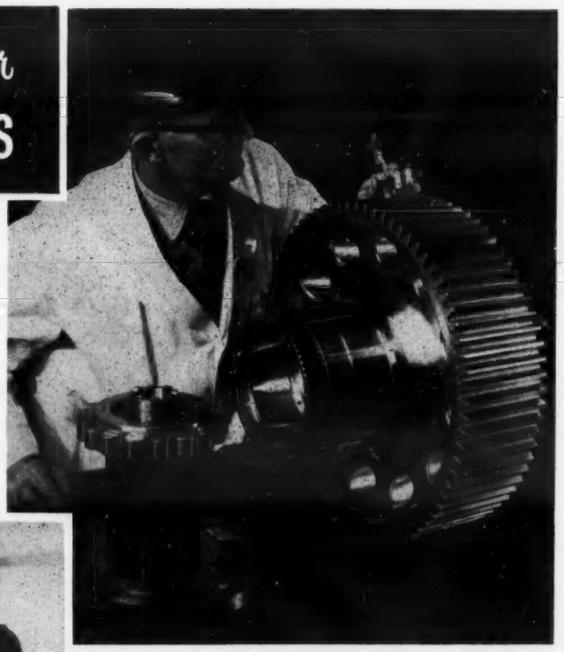

The main gear wheel and hub assembly of the Bristol Type 192 twin-engined, tandem-rotor helicopter being measured to an accuracy of ·0001. Reproduced by courtesy of Westland Aircraft Ltd.

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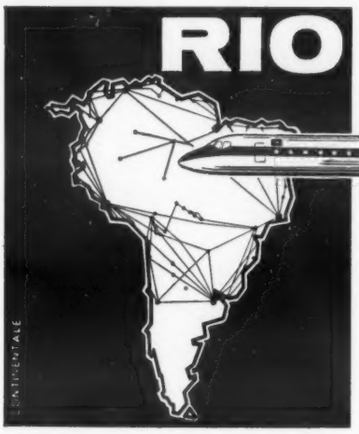

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Pilot Examiner

The Directorate of Civil Aviation invites applications for one post of pilot examiner, stationed at Beirut, Lebanon.

The pilot examiner will be required to conduct flying tests for pilots' licences and ratings as well as for pilots seeking to be delegated pilot examiners for instrument rating renewal.

CONDITIONS

AGE: candidates must be between 25 and 55 years of age on January 1, 1961.

QUALIFICATIONS AND EXPERIENCE: candidate must have:

i) an Airline Transport Pilot's Licence with a flight instructor rating.

ii) not less than 10,000 hrs. flying experience including at least 5000 hrs as pilot in command. Recent command experience on two or more of the following aircraft types is desirable: DC-4, DC-6, Viscount, Comet, Caravelle.

iii) sound technical knowledge of aviation matters including civil aircraft operations, navigation...

iv) preference will be given to pilots having performed similar work in other civil aviation departments.

MONTHLY SALARY OFFERED: $1000.— No other allowances, non pensionable.

LENGTH OF CONTRACT: one year renewable.

APPLICATION must include detailed curriculum vitae and be addressed to the Directorate of Civil Aviation, Beirut, Lebanon, and airmailed not later than December 1, 1961.

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